FIG. 1

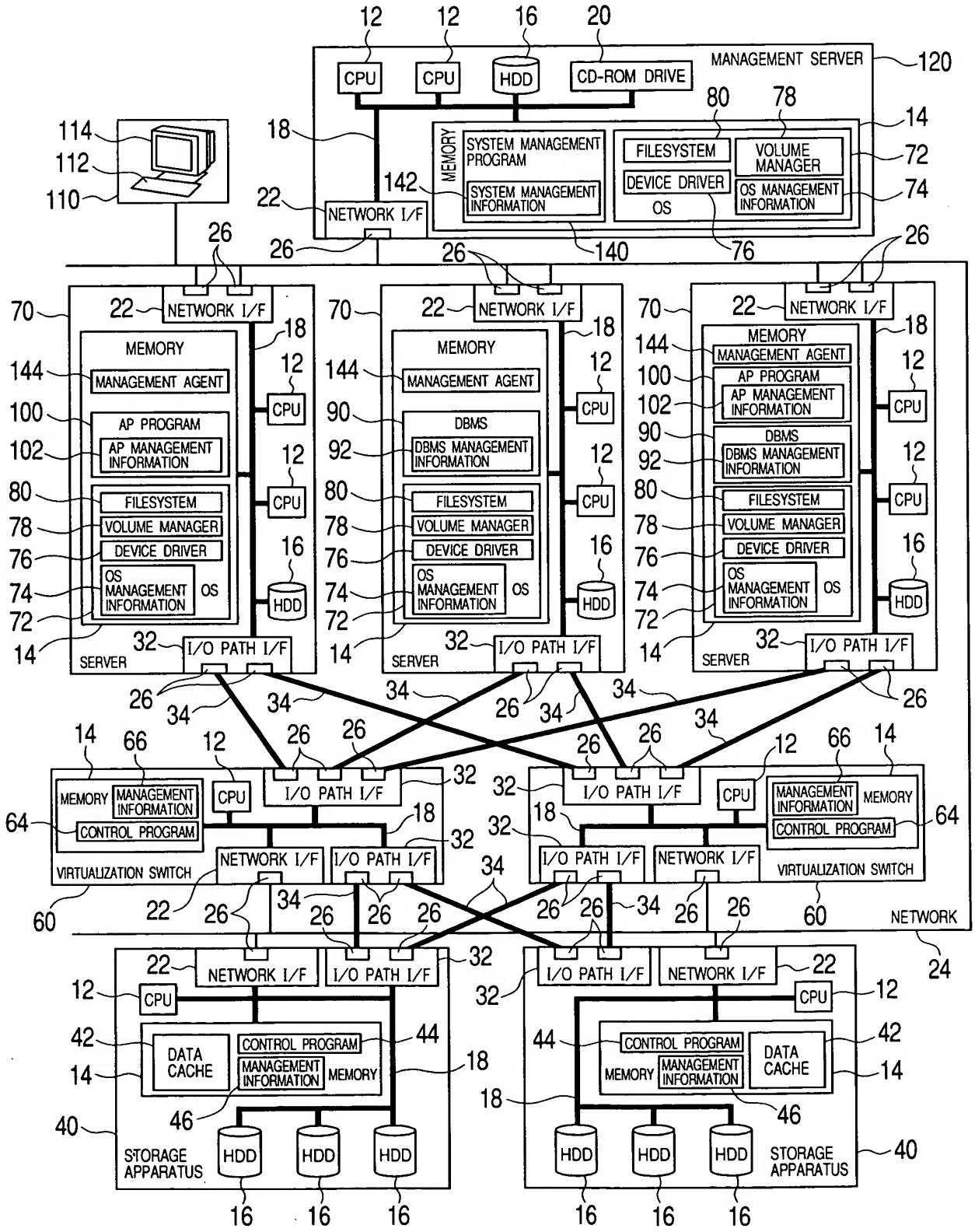

MANAGEMENT SERVER
120
CPU
CPU
HDD
CD-ROM DRIVE
MEMORY
SYSTEM MANAGEMENT PROGRAM
SYSTEM MANAGEMENT INFORMATION
FILESYSTEM
VOLUME MANAGER
DEVICE DRIVER
OS MANAGEMENT INFORMATION
OS
NETWORK I/F
140
76
SERVER
I/O PATH I/F
MANAGEMENT AGENT
AP PROGRAM
AP MANAGEMENT INFORMATION
DBMS
DBMS MANAGEMENT INFORMATION
VIRTUALIZATION SWITCH
CONTROL PROGRAM
NETWORK
STORAGE APPARATUS
DATA CACHE
HDD

FIG. 2

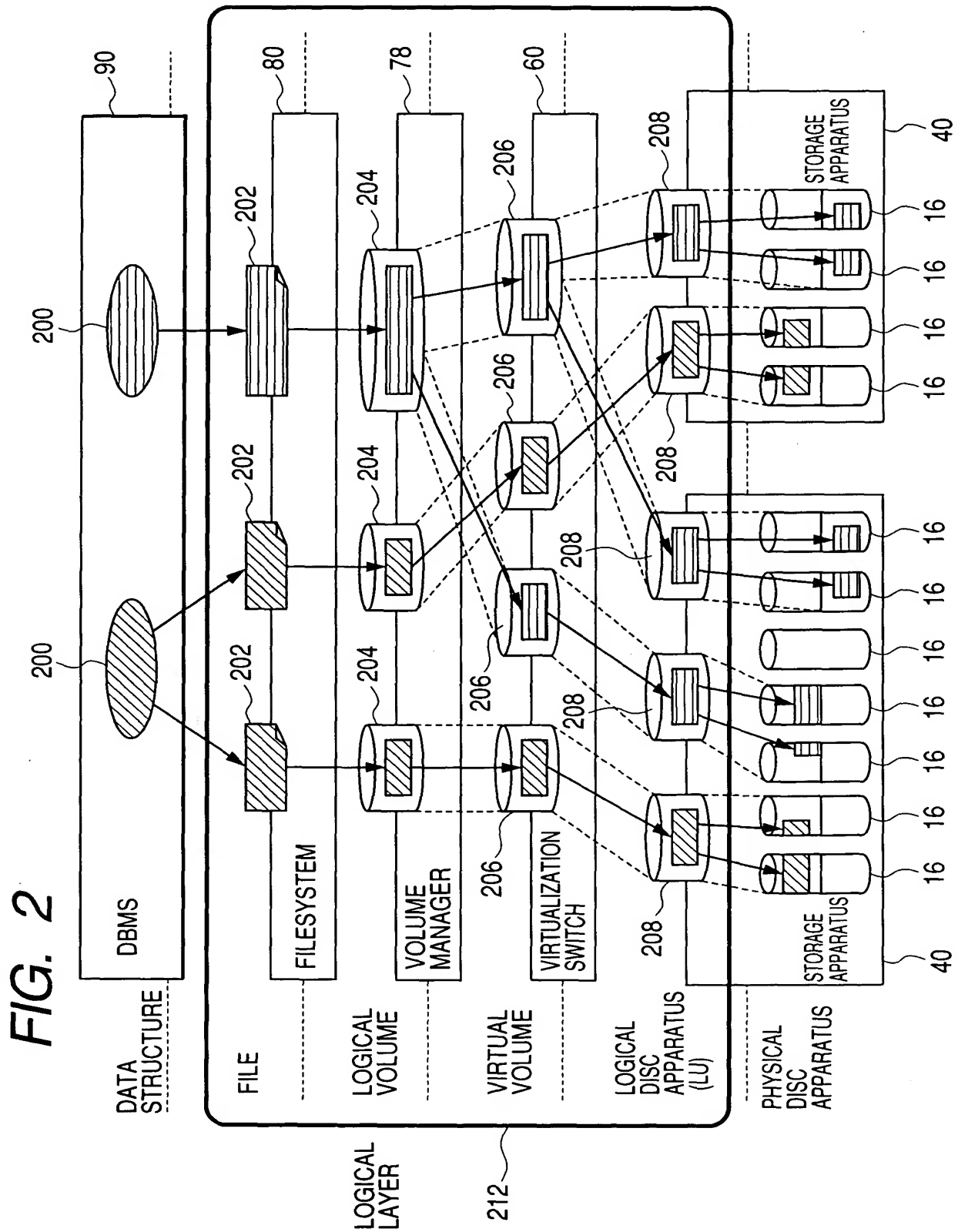

DATA STRUCTURE
DBMS
FILE
FILESYSTEM
LOGICAL VOLUME
VOLUME MANAGER
VIRTUAL VOLUME
VIRTUALIZATION SWITCH
LOGICAL DISC APPARATUS (LU)
PHYSICAL DISC APPARATUS
STORAGE APPARATUS
STORAGE APPARATUS
LOGICAL LAYER
212
90
80
78
60
200
200
202
202
202
204
204
204
206
206
206
206
208
208
208
208
16
40
40

FIG. 3

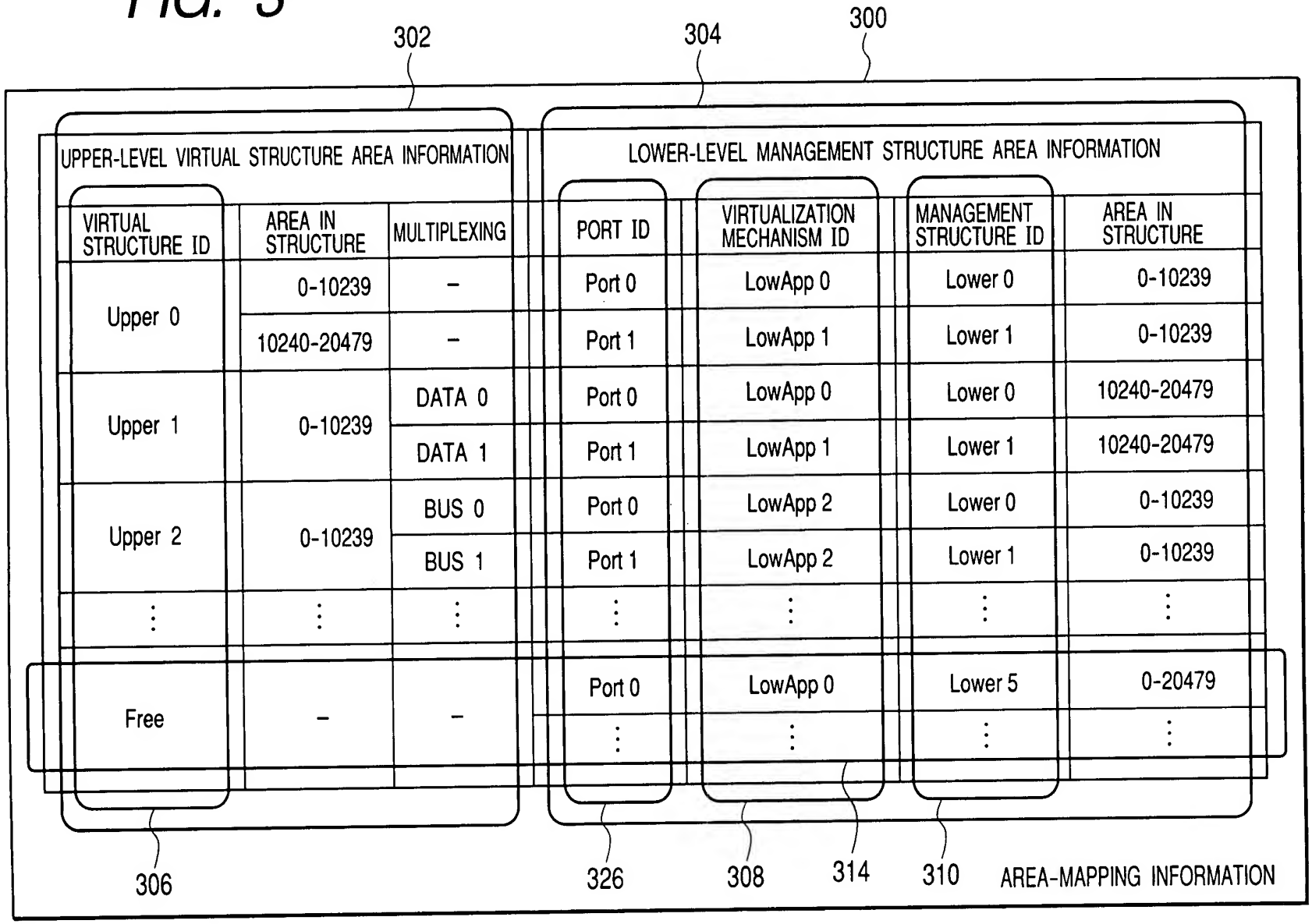

302
304
300
UPPER-LEVEL VIRTUAL STRUCTURE AREA INFORMATION
VIRTUAL STRUCTURE ID
AREA IN STRUCTURE
MULTIPLEXING
Upper 0
0-10239
–
10240-20479
–
Upper 1
0-10239
DATA 0
DATA 1
Upper 2
0-10239
BUS 0
BUS 1
Free
–
–
LOWER-LEVEL MANAGEMENT STRUCTURE AREA INFORMATION
PORT ID
VIRTUALIZATION MECHANISM ID
MANAGEMENT STRUCTURE ID
AREA IN STRUCTURE
Port 0
LowApp 0
Lower 0
0-10239
Port 1
LowApp 1
Lower 1
0-10239
Port 0
LowApp 0
Lower 0
10240-20479
Port 1
LowApp 1
Lower 1
10240-20479
Port 0
LowApp 2
Lower 0
0-10239
Port 1
LowApp 2
Lower 1
0-10239
Port 0
LowApp 0
Lower 5
0-20479
306
326
308
314
310
AREA-MAPPING INFORMATION

FIG. 4

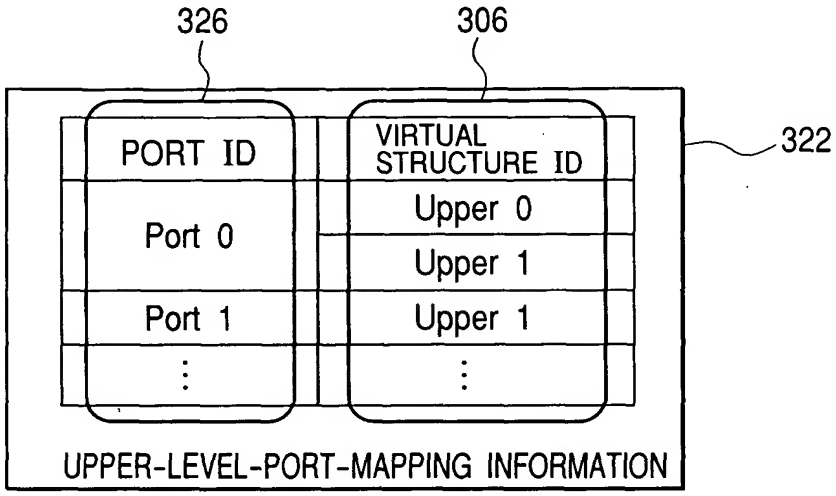

326
306
322
PORT ID
VIRTUAL STRUCTURE ID
Port 0
Upper 0
Upper 1
Port 1
Upper 1
UPPER-LEVEL-PORT-MAPPING INFORMATION

FIG. 5

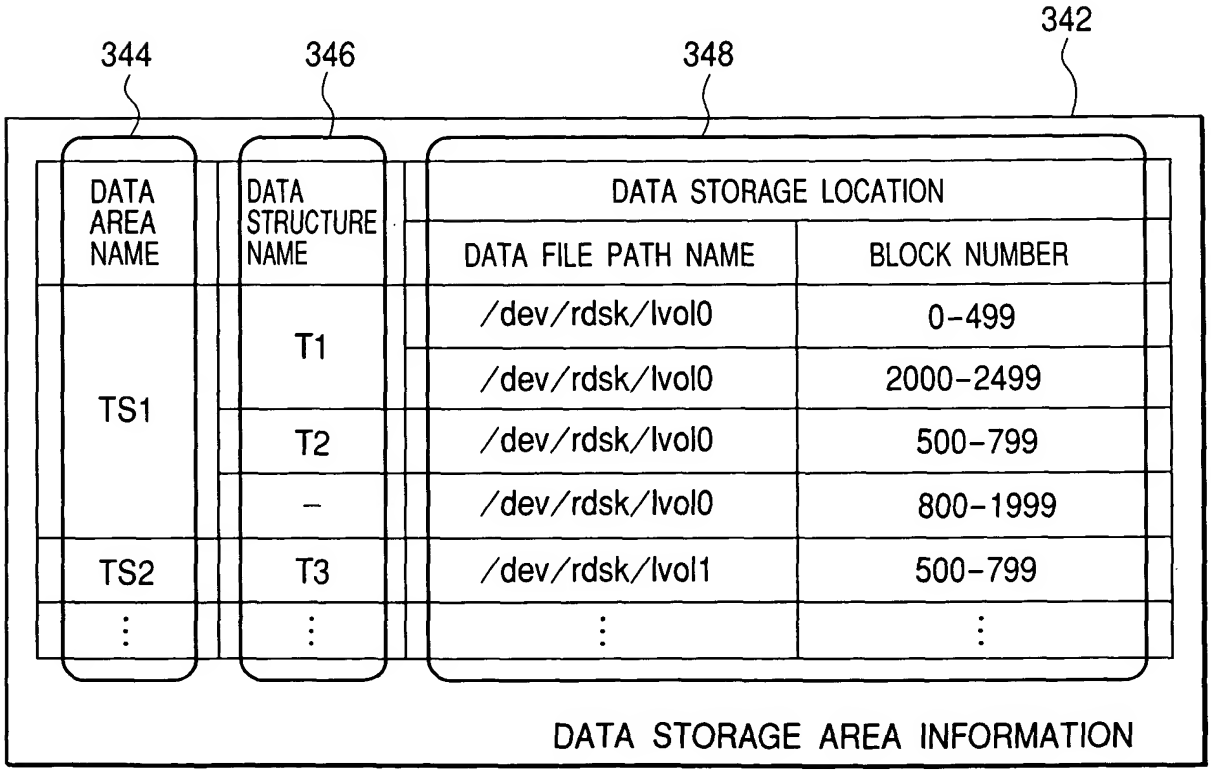

342
344
346
348
DATA AREA NAME
DATA STRUCTURE NAME
DATA STORAGE LOCATION
DATA FILE PATH NAME
BLOCK NUMBER
TS1
T1
/dev/rdsk/lvol0
0-499
/dev/rdsk/lvol0
2000-2499
T2
/dev/rdsk/lvol0
500-799
–
/dev/rdsk/lvol0
800-1999
TS2
T3
/dev/rdsk/lvol1
500-799
DATA STORAGE AREA INFORMATION

FIG. 6

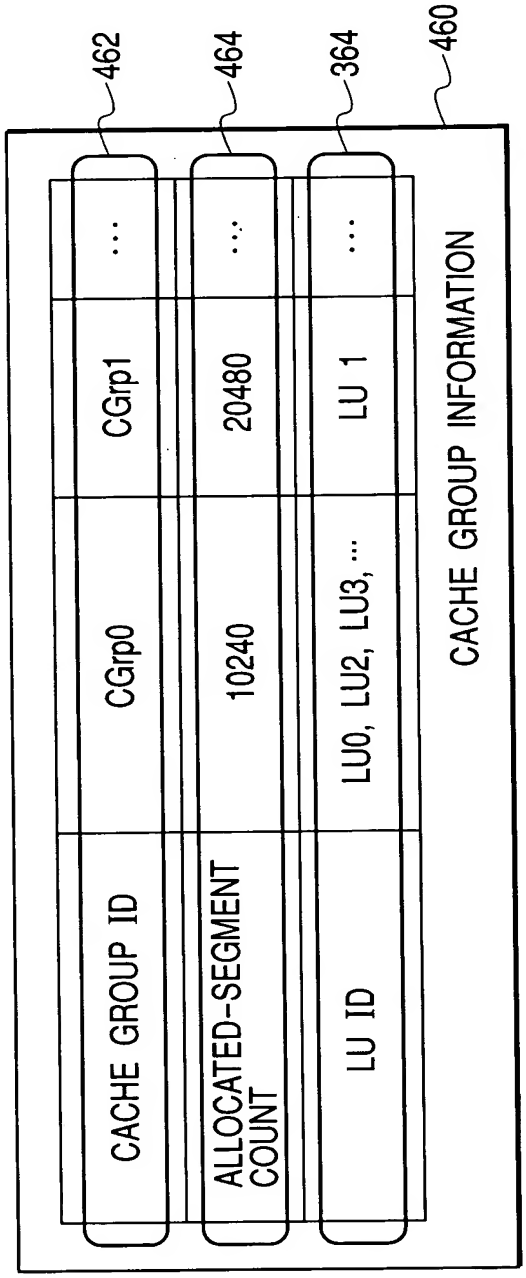

462
464
364
460
CACHE GROUP ID
CGrp0
CGrp1
...
ALLOCATED-SEGMENT COUNT
10240
20480
...
LU ID
LU0, LU2, LU3, ...
LU 1
...
CACHE GROUP INFORMATION

FIG. 7

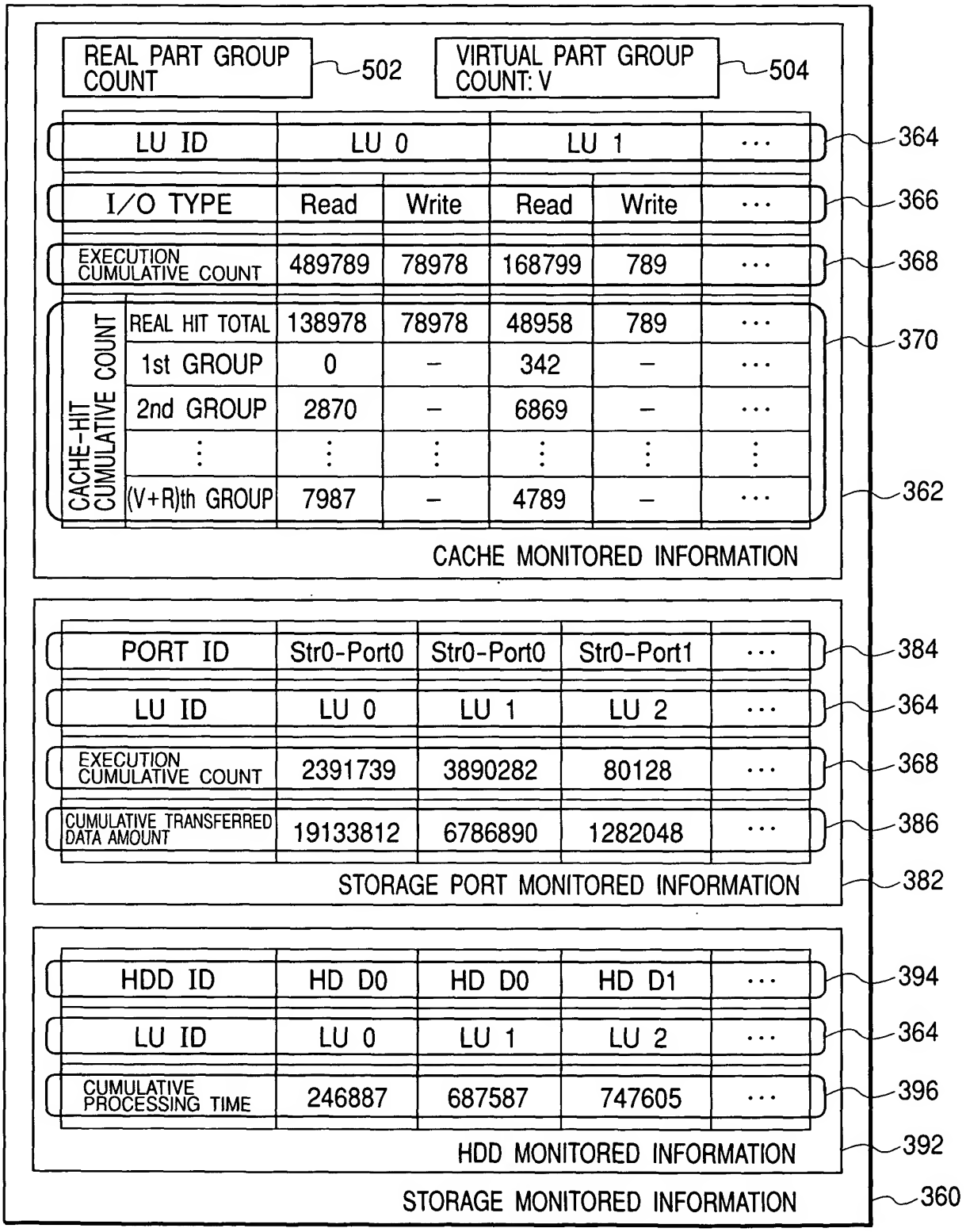

REAL PART GROUP COUNT
502
VIRTUAL PART GROUP COUNT: V
504
LU ID
LU 0
LU 1
364
I/O TYPE
Read
Write
Read
Write
366
EXECUTION CUMULATIVE COUNT
489789
78978
168799
789
368
CACHE-HIT CUMULATIVE COUNT
REAL HIT TOTAL
138978
78978
48958
789
1st GROUP
0
342
2nd GROUP
2870
6869
(V+R)th GROUP
7987
4789
370
362
CACHE MONITORED INFORMATION
PORT ID
Str0-Port0
Str0-Port0
Str0-Port1
384
LU ID
LU 0
LU 1
LU 2
364
EXECUTION CUMULATIVE COUNT
2391739
3890282
80128
368
CUMULATIVE TRANSFERRED DATA AMOUNT
19133812
6786890
1282048
386
STORAGE PORT MONITORED INFORMATION
382
HDD ID
HD D0
HD D0
HD D1
394
LU ID
LU 0
LU 1
LU 2
364
CUMULATIVE PROCESSING TIME
246887
687587
747605
396
HDD MONITORED INFORMATION
392
STORAGE MONITORED INFORMATION
360

FIG. 8

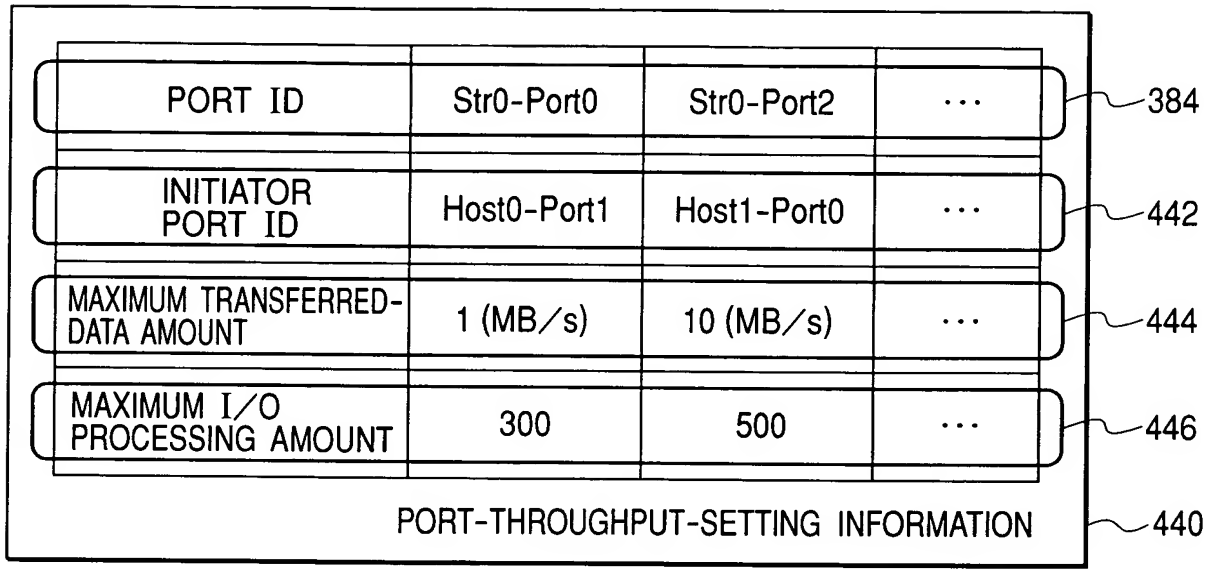

PORT ID
Str0-Port0
Str0-Port2
···
384
INITIATOR PORT ID
Host0-Port1
Host1-Port0
···
442
MAXIMUM TRANSFERRED-DATA AMOUNT
1 (MB/s)
10 (MB/s)
···
444
MAXIMUM I/O PROCESSING AMOUNT
300
500
···
446
PORT-THROUGHPUT-SETTING INFORMATION
440

FIG. 9

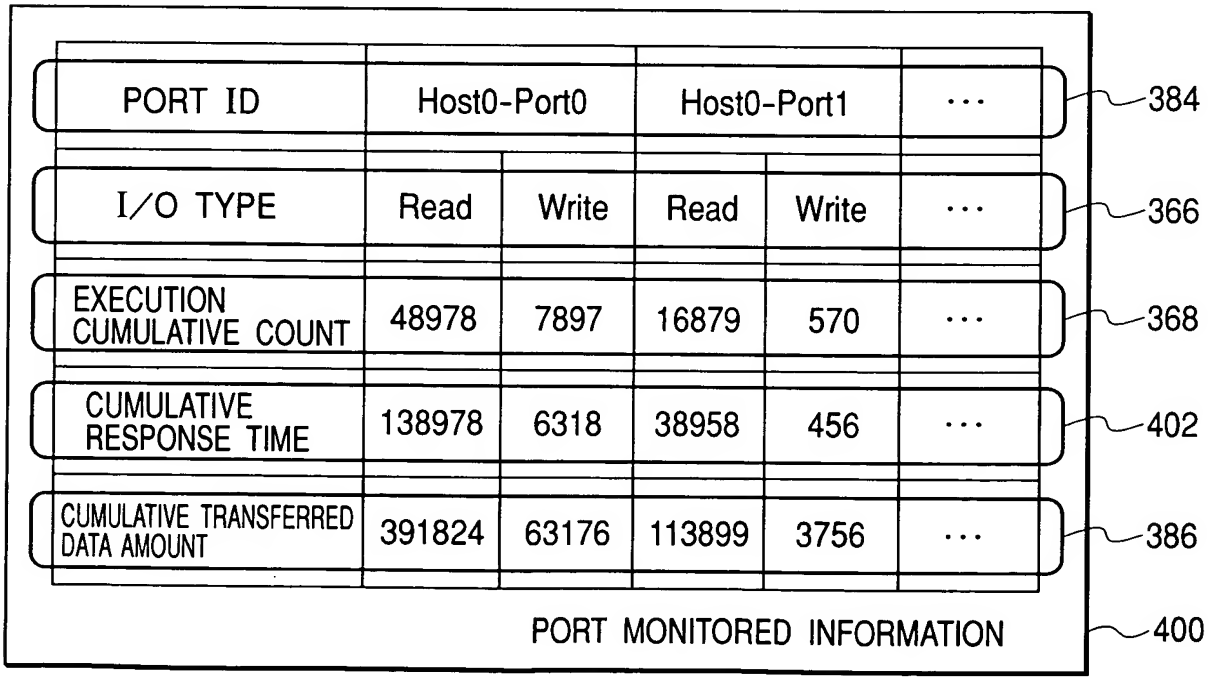

PORT ID
Host0-Port0
Host0-Port1
···
384
I/O TYPE
Read
Write
Read
Write
···
366
EXECUTION CUMULATIVE COUNT
48978
7897
16879
570
···
368
CUMULATIVE RESPONSE TIME
138978
6318
38958
456
···
402
CUMULATIVE TRANSFERRED DATA AMOUNT
391824
63176
113899
3756
···
386
PORT MONITORED INFORMATION
400

FIG. 10

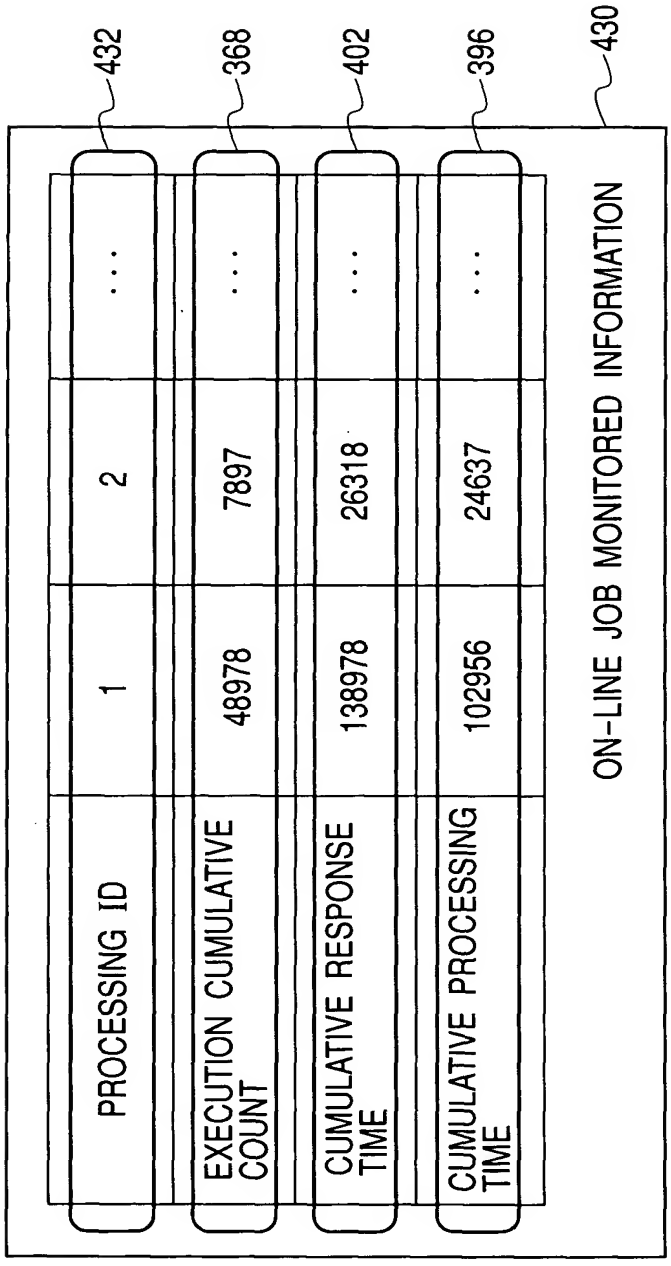

ON-LINE JOB MONITORED INFORMATION
PROCESSING ID
1
2
...
EXECUTION CUMULATIVE COUNT
48978
7897
...
CUMULATIVE RESPONSE TIME
138978
26318
...
CUMULATIVE PROCESSING TIME
102956
24637
...
432
368
402
396
430

FIG. 11

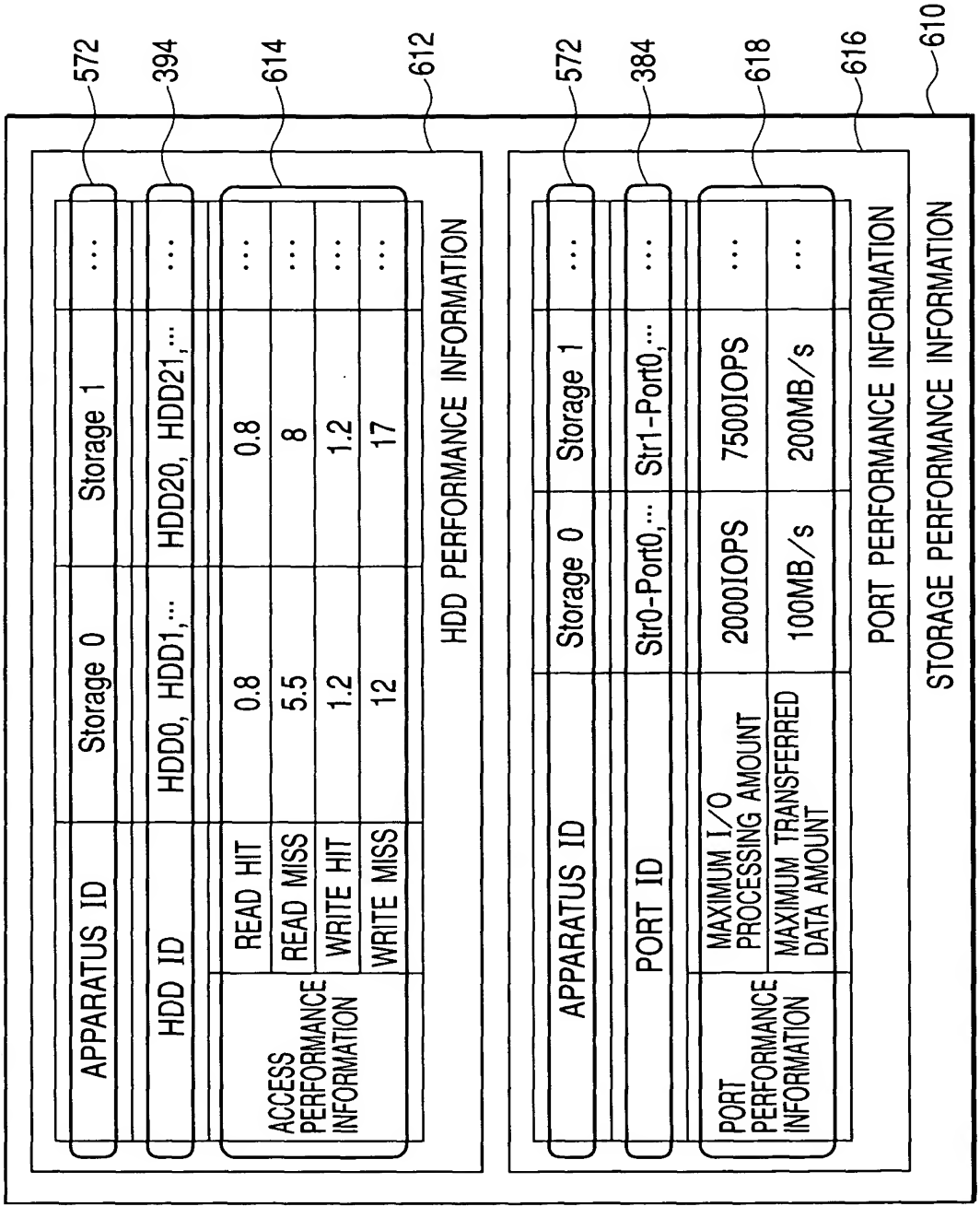

572
394
614
612
APPARATUS ID
Storage 0
Storage 1
...
HDD ID
HDD0, HDD1,...
HDD20, HDD21,...
ACCESS PERFORMANCE INFORMATION
READ HIT
READ MISS
WRITE HIT
WRITE MISS
0.8
5.5
1.2
12
0.8
8
1.2
17
HDD PERFORMANCE INFORMATION
572
384
618
616
610
APPARATUS ID
Storage 0
Storage 1
PORT ID
Str0-Port0,...
Str1-Port0,...
PORT PERFORMANCE INFORMATION
MAXIMUM I/O PROCESSING AMOUNT
MAXIMUM TRANSFERRED DATA AMOUNT
2000IOPS
7500IOPS
100MB/s
200MB/s
PORT PERFORMANCE INFORMATION
STORAGE PERFORMANCE INFORMATION

FIG. 12

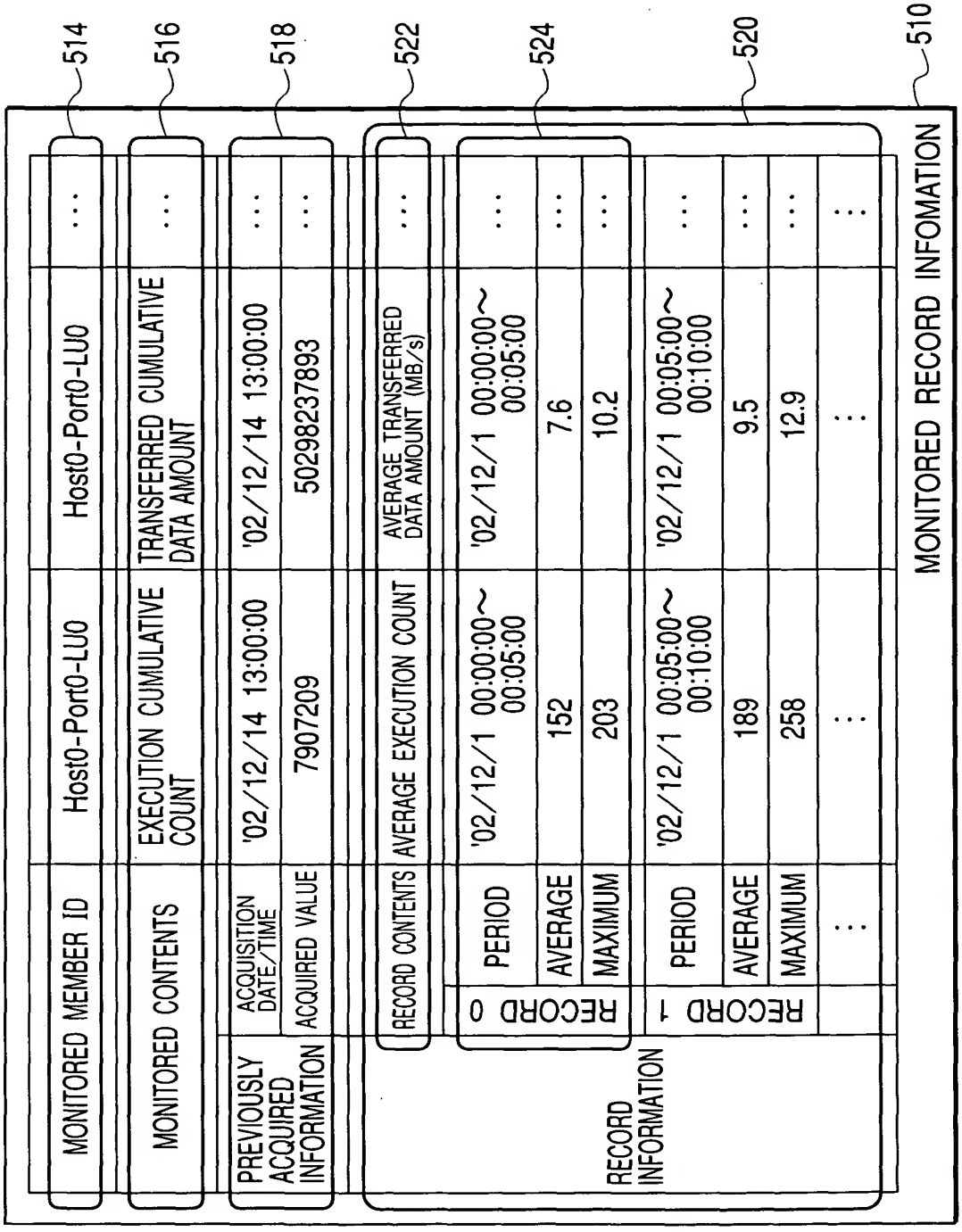

514
516
518
522
524
520
510
MONITORED MEMBER ID
Host0-Port0-LU0
Host0-Port0-LU0
MONITORED CONTENTS
EXECUTION CUMULATIVE COUNT
TRANSFERRED CUMULATIVE DATA AMOUNT
PREVIOUSLY ACQUIRED INFORMATION
ACQUISITION DATE/TIME
'02/12/14 13:00:00
'02/12/14 13:00:00
ACQUIRED VALUE
7907209
50298237893
RECORD INFORMATION
RECORD CONTENTS
AVERAGE EXECUTION COUNT
AVERAGE TRANSFERRED DATA AMOUNT (MB/s)
RECORD 0
PERIOD
'02/12/1 00:00:00~ 00:05:00
'02/12/1 00:00:00~ 00:05:00
AVERAGE
152
7.6
MAXIMUM
203
10.2
RECORD 1
PERIOD
'02/12/1 00:05:00~ 00:10:00
'02/12/1 00:05:00~ 00:10:00
AVERAGE
189
9.5
MAXIMUM
258
12.9
MONITORED RECORD INFOMATION

FIG. 13

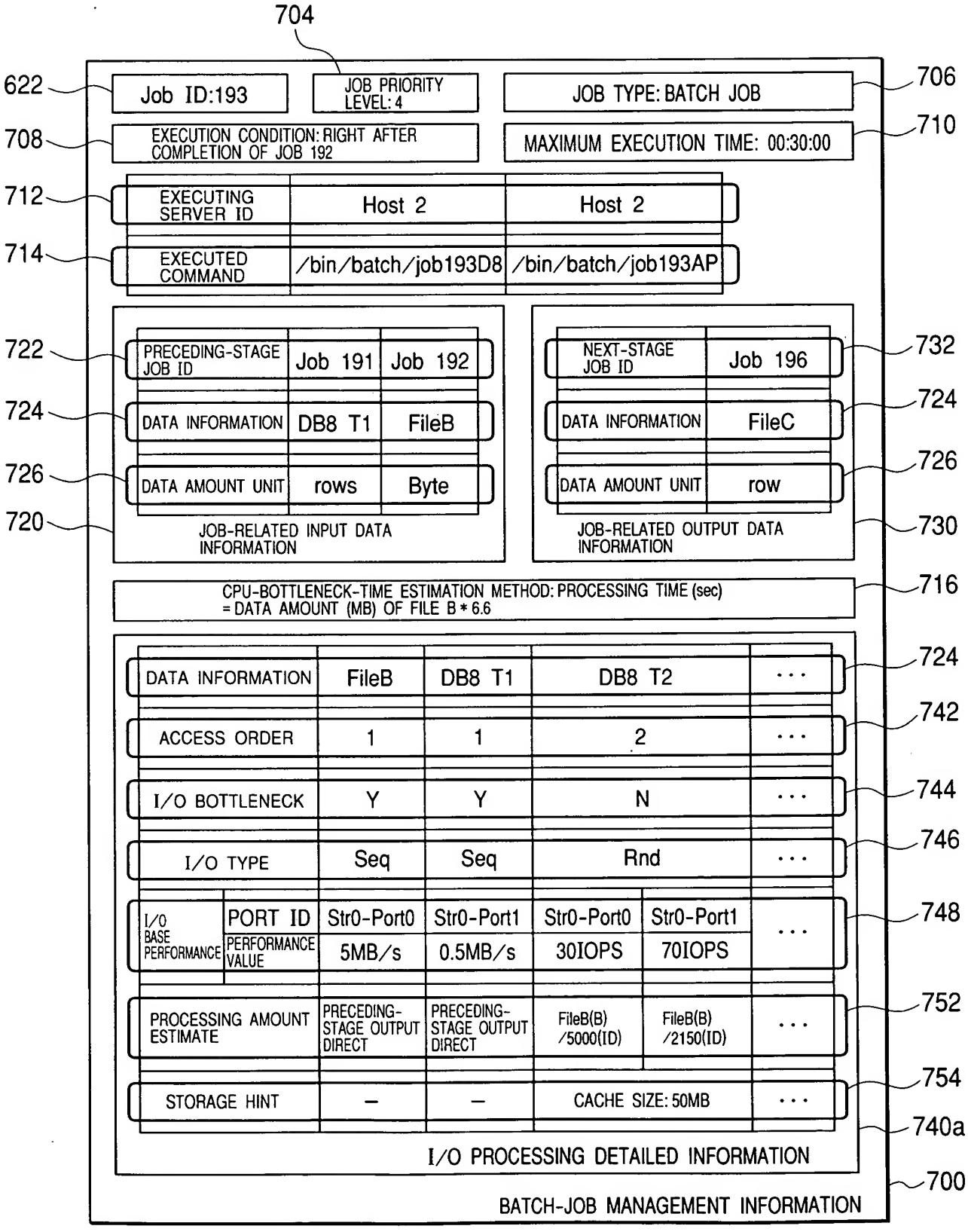

704
622
Job ID:193
JOB PRIORITY LEVEL: 4
JOB TYPE: BATCH JOB
706
708
EXECUTION CONDITION: RIGHT AFTER COMPLETION OF JOB 192
MAXIMUM EXECUTION TIME: 00:30:00
710
712
EXECUTING SERVER ID
Host 2
Host 2
714
EXECUTED COMMAND
/bin/batch/job193D8
/bin/batch/job193AP
722
PRECEDING-STAGE JOB ID
Job 191
Job 192
724
DATA INFORMATION
DB8 T1
FileB
726
DATA AMOUNT UNIT
rows
Byte
720
JOB-RELATED INPUT DATA INFORMATION
NEXT-STAGE JOB ID
Job 196
732
DATA INFORMATION
FileC
724
DATA AMOUNT UNIT
row
726
JOB-RELATED OUTPUT DATA INFORMATION
730
CPU-BOTTLENECK-TIME ESTIMATION METHOD: PROCESSING TIME (sec) = DATA AMOUNT (MB) OF FILE B * 6.6
716
DATA INFORMATION
FileB
DB8 T1
DB8 T2
724
ACCESS ORDER
1
1
2
742
I/O BOTTLENECK
Y
Y
N
744
I/O TYPE
Seq
Seq
Rnd
746
I/O BASE PERFORMANCE
PORT ID
Str0-Port0
Str0-Port1
Str0-Port0
Str0-Port1
748
PERFORMANCE VALUE
5MB/s
0.5MB/s
30IOPS
70IOPS
PROCESSING AMOUNT ESTIMATE
PRECEDING-STAGE OUTPUT DIRECT
PRECEDING-STAGE OUTPUT DIRECT
FileB(B) /5000(ID)
FileB(B) /2150(ID)
752
STORAGE HINT
–
–
CACHE SIZE: 50MB
754
740a
I/O PROCESSING DETAILED INFORMATION
700
BATCH-JOB MANAGEMENT INFORMATION

FIG. 14

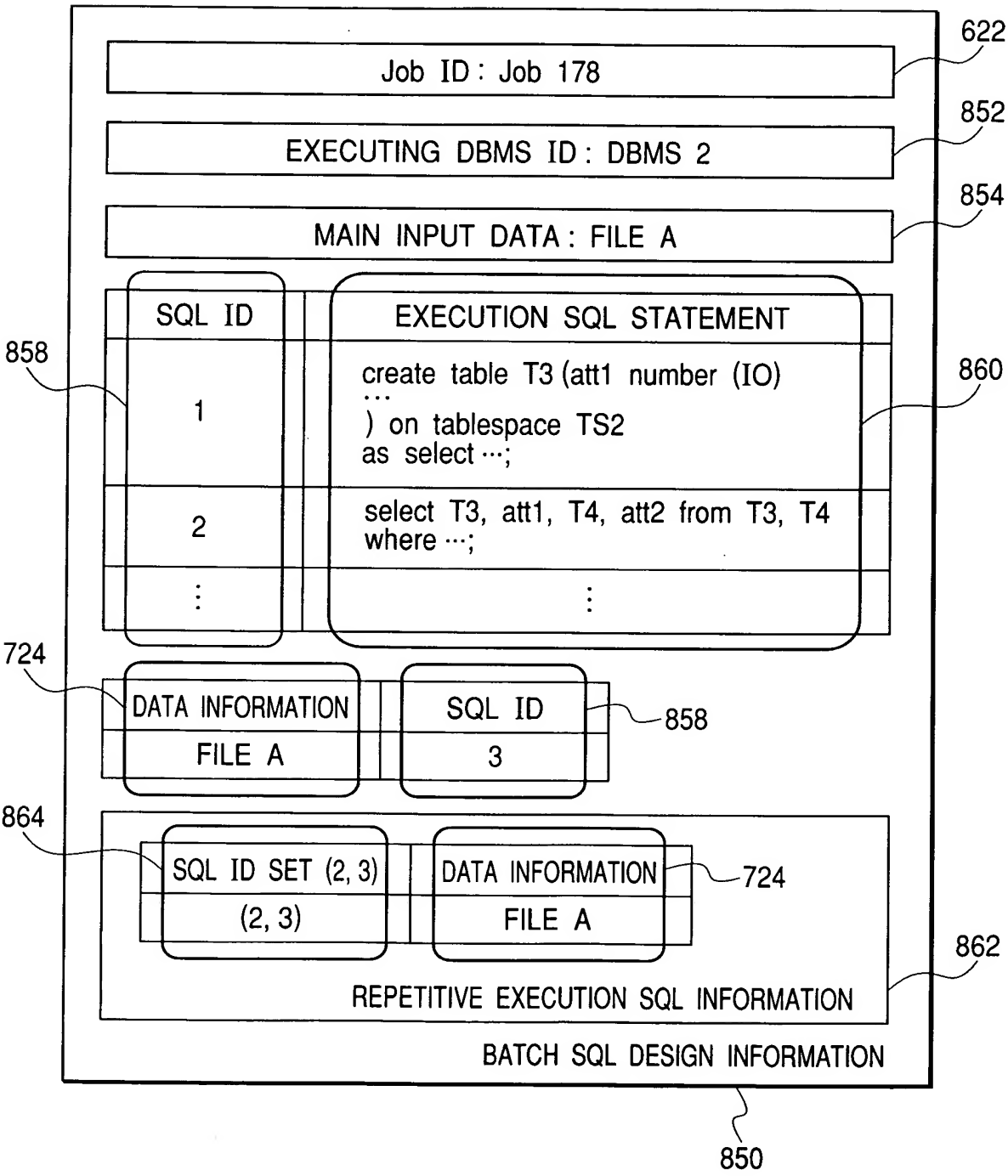

622
Job ID : Job 178
852
EXECUTING DBMS ID : DBMS 2
854
MAIN INPUT DATA : FILE A
858
SQL ID
EXECUTION SQL STATEMENT
1
create table T3 (att1 number (IO)
...
) on tablespace TS2
as select ...;
860
2
select T3, att1, T4, att2 from T3, T4
where ...;
724
DATA INFORMATION
FILE A
SQL ID
3
858
864
SQL ID SET (2, 3)
(2, 3)
DATA INFORMATION
FILE A
724
862
REPETITIVE EXECUTION SQL INFORMATION
BATCH SQL DESIGN INFORMATION
850

FIG. 15

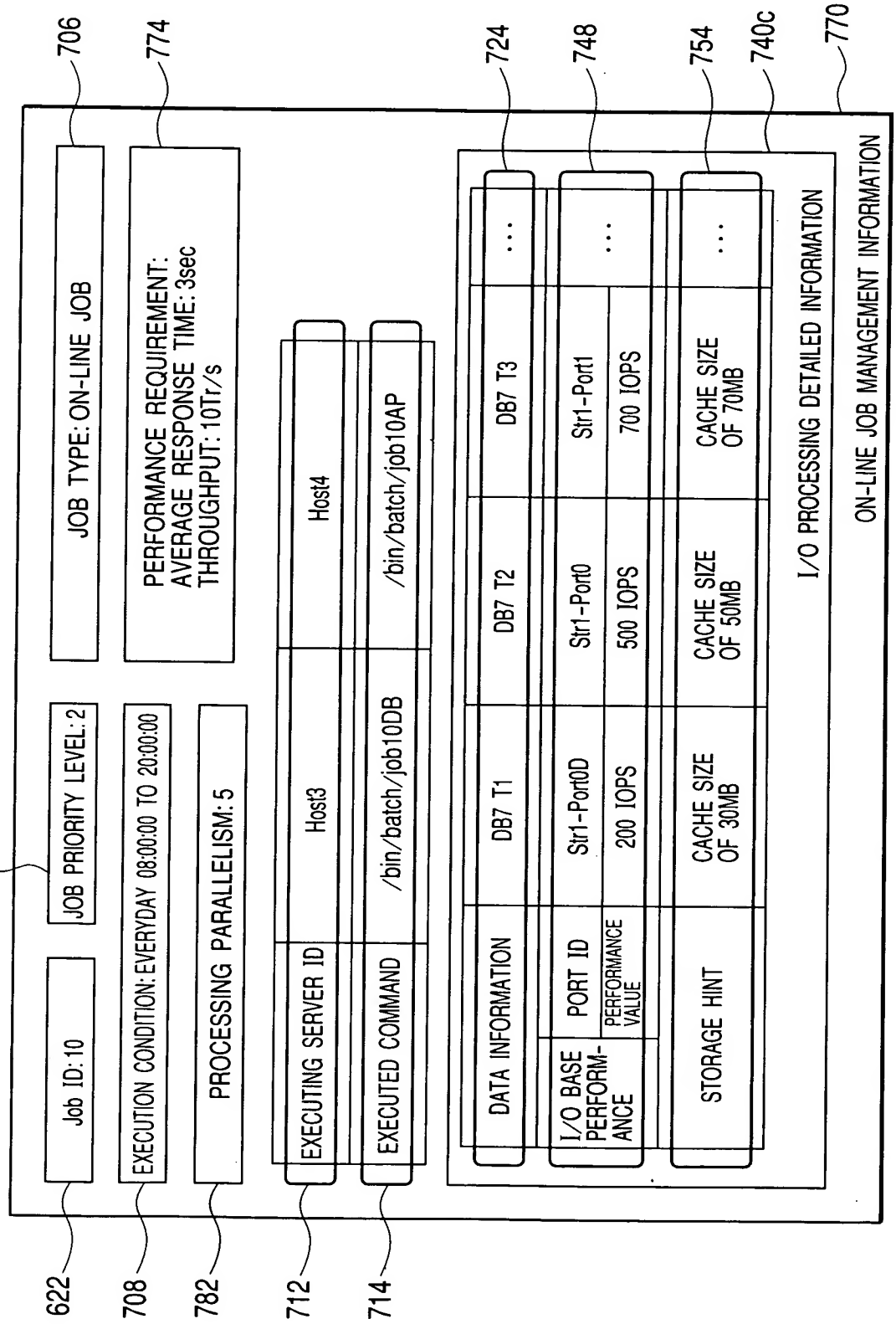

704
706
774
724
748
754
740c
770
Job ID: 10
JOB PRIORITY LEVEL: 2
JOB TYPE: ON-LINE JOB
EXECUTION CONDITION: EVERYDAY 08:00:00 TO 20:00:00
PERFORMANCE REQUIREMENT: AVERAGE RESPONSE TIME: 3sec THROUGHPUT: 10Tr/s
PROCESSING PARALLELISM: 5
EXECUTING SERVER ID
Host3
Host4
EXECUTED COMMAND
/bin/batch/job10DB
/bin/batch/job10AP
DATA INFORMATION
DB7 T1
DB7 T2
DB7 T3
I/O BASE PERFORM-ANCE
PORT ID
PERFORMANCE VALUE
Str1-Port0D
200 IOPS
Str1-Port0
500 IOPS
Str1-Port1
700 IOPS
STORAGE HINT
CACHE SIZE OF 30MB
CACHE SIZE OF 50MB
CACHE SIZE OF 70MB
I/O PROCESSING DETAILED INFORMATION
ON-LINE JOB MANAGEMENT INFORMATION
622
708
782
712
714

FIG. 16

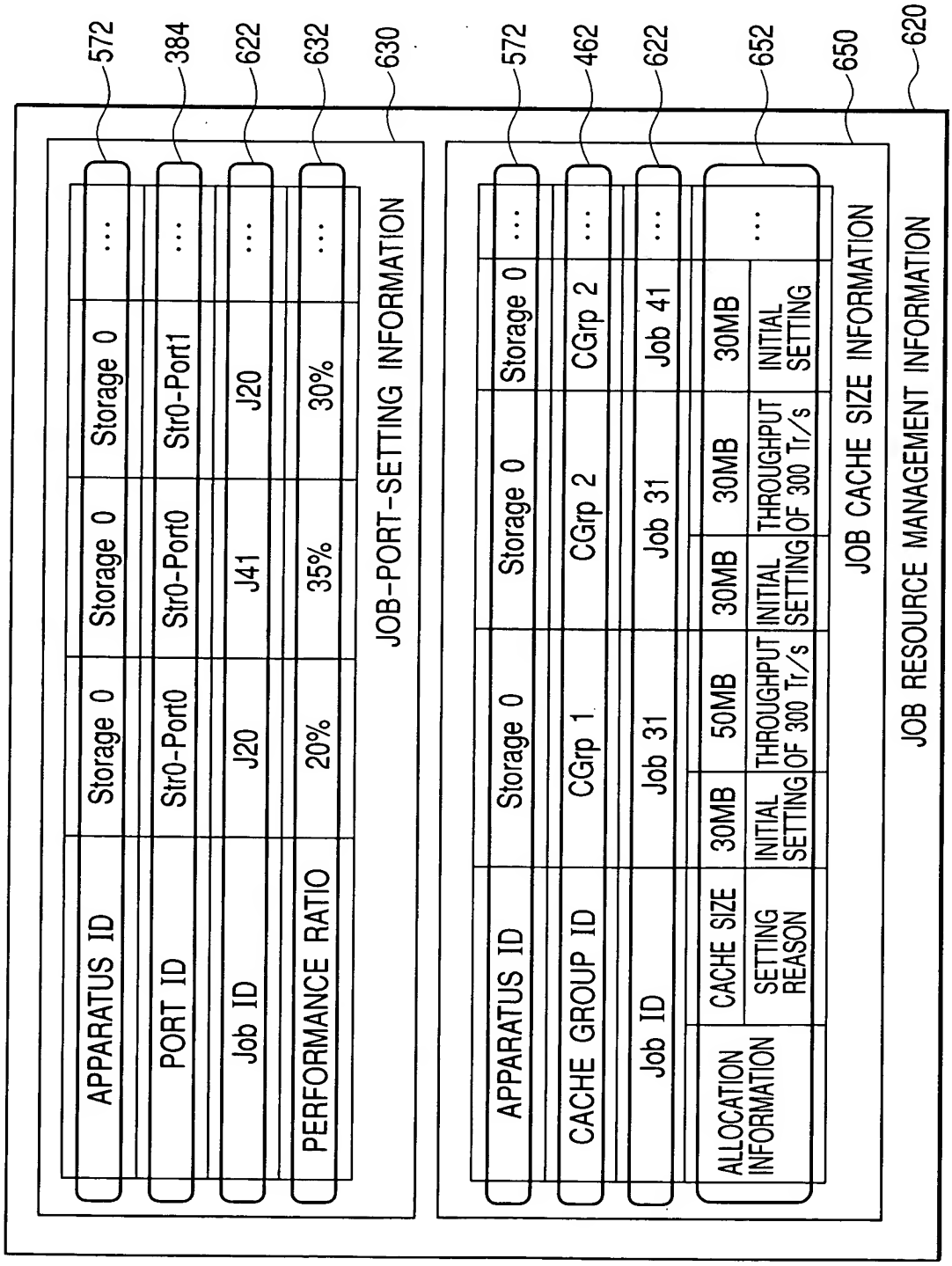

620
JOB RESOURCE MANAGEMENT INFORMATION
630
JOB-PORT-SETTING INFORMATION
572
384
622
632
APPARATUS ID
PORT ID
Job ID
PERFORMANCE RATIO
Storage 0
Str0-Port0
Str0-Port1
J20
J41
20%
35%
30%
650
JOB CACHE SIZE INFORMATION
572
462
622
652
APPARATUS ID
CACHE GROUP ID
Job ID
ALLOCATION INFORMATION
CACHE SIZE
SETTING REASON
CGrp 1
CGrp 2
Job 31
Job 41
50MB
30MB
THROUGHPUT OF 300 Tr/s
INITIAL SETTING

FIG. 17

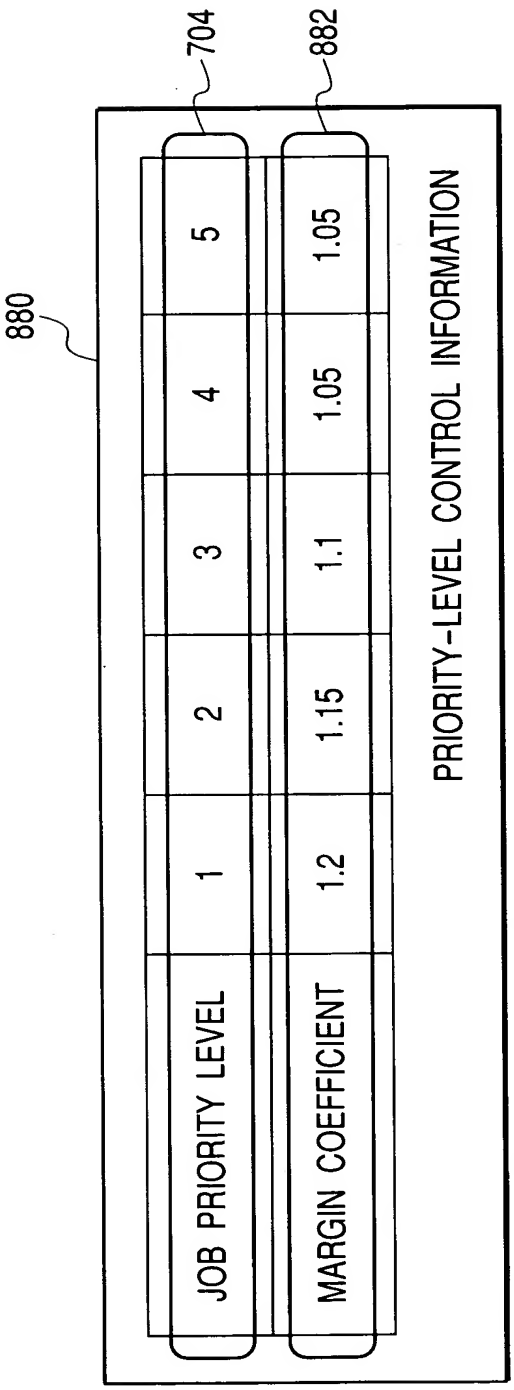

880
704
882
JOB PRIORITY LEVEL
1
2
3
4
5
MARGIN COEFFICIENT
1.2
1.15
1.1
1.05
1.05
PRIORITY-LEVEL CONTROL INFORMATION

FIG. 18

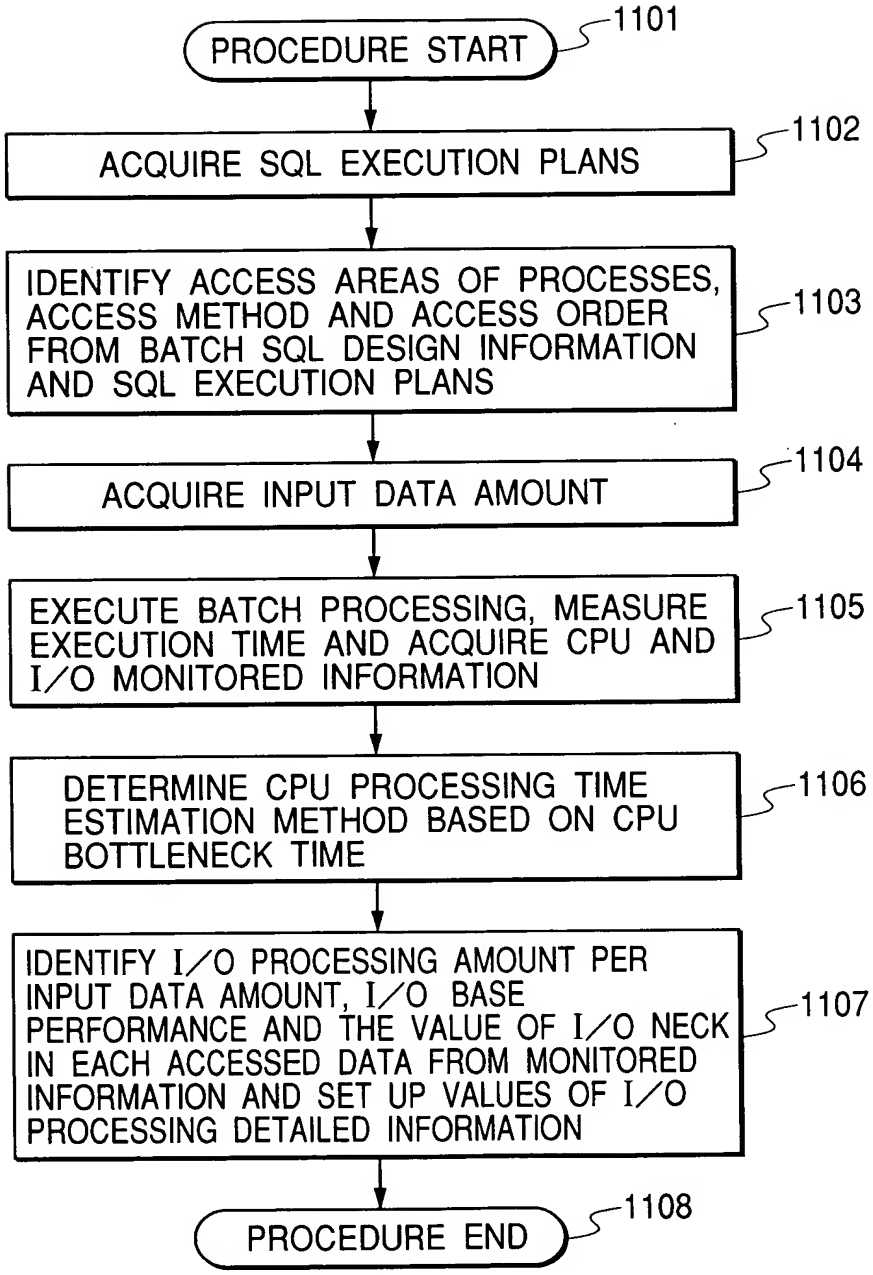

PROCEDURE START
1101
ACQUIRE SQL EXECUTION PLANS
1102
IDENTIFY ACCESS AREAS OF PROCESSES, ACCESS METHOD AND ACCESS ORDER FROM BATCH SQL DESIGN INFORMATION AND SQL EXECUTION PLANS
1103
ACQUIRE INPUT DATA AMOUNT
1104
EXECUTE BATCH PROCESSING, MEASURE EXECUTION TIME AND ACQUIRE CPU AND I/O MONITORED INFORMATION
1105
DETERMINE CPU PROCESSING TIME ESTIMATION METHOD BASED ON CPU BOTTLENECK TIME
1106
IDENTIFY I/O PROCESSING AMOUNT PER INPUT DATA AMOUNT, I/O BASE PERFORMANCE AND THE VALUE OF I/O NECK IN EACH ACCESSED DATA FROM MONITORED INFORMATION AND SET UP VALUES OF I/O PROCESSING DETAILED INFORMATION
1107
PROCEDURE END
1108

FIG. 19

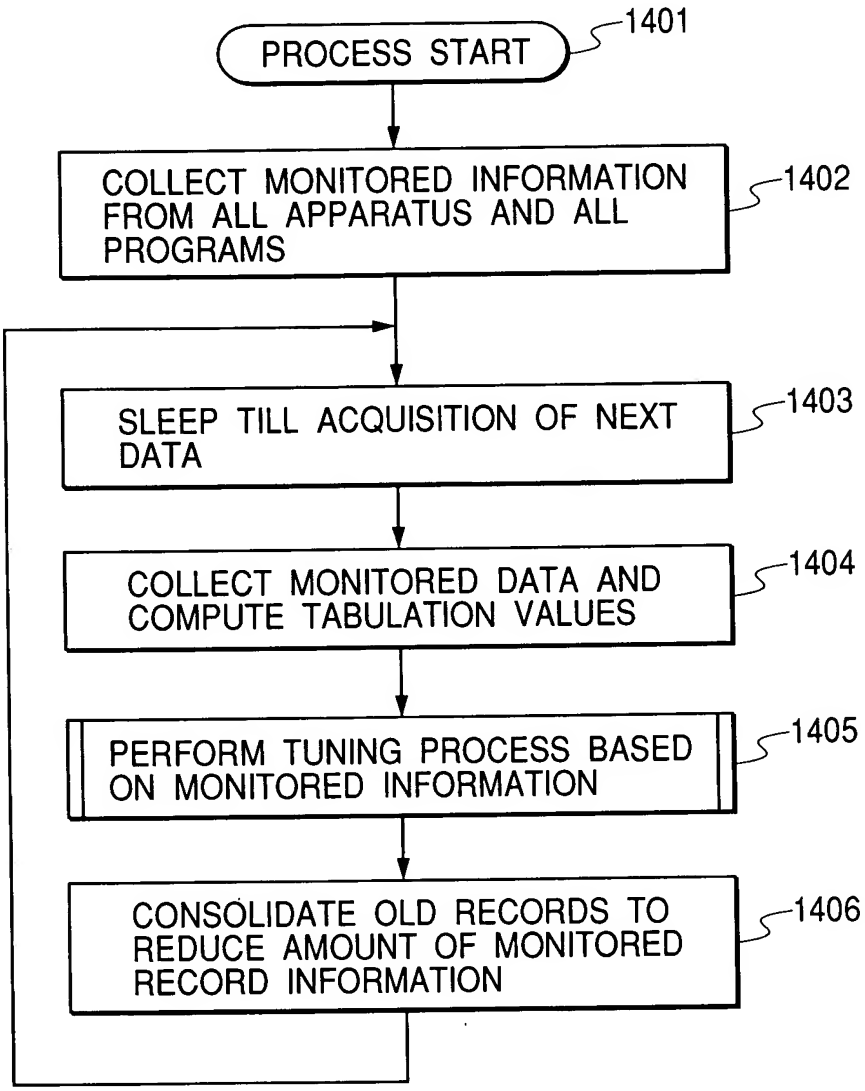

PROCESS START
1401
COLLECT MONITORED INFORMATION FROM ALL APPARATUS AND ALL PROGRAMS
1402
SLEEP TILL ACQUISITION OF NEXT DATA
1403
COLLECT MONITORED DATA AND COMPUTE TABULATION VALUES
1404
PERFORM TUNING PROCESS BASED ON MONITORED INFORMATION
1405
CONSOLIDATE OLD RECORDS TO REDUCE AMOUNT OF MONITORED RECORD INFORMATION
1406

FIG. 20

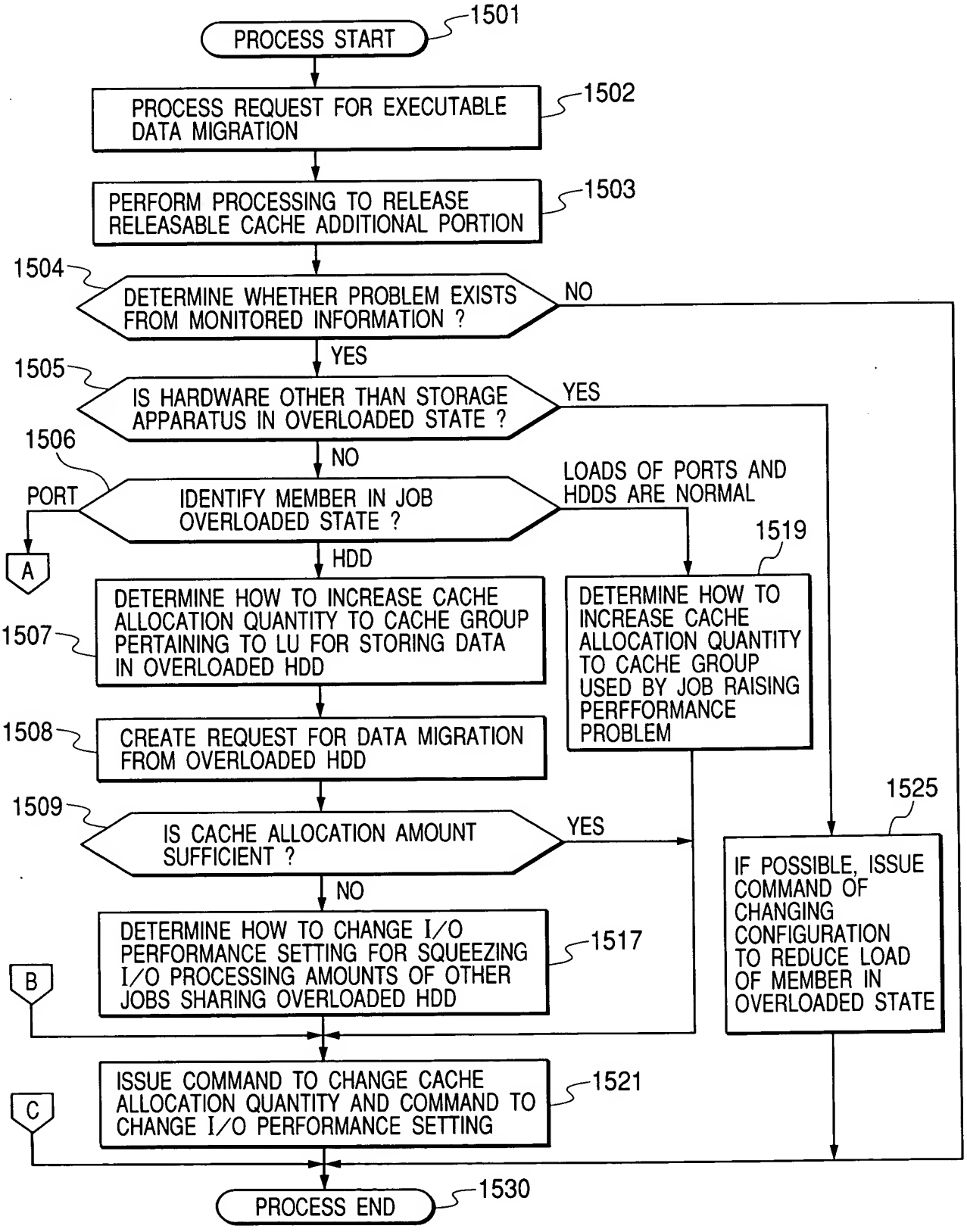

PROCESS START
1501
PROCESS REQUEST FOR EXECUTABLE DATA MIGRATION
1502
PERFORM PROCESSING TO RELEASE RELEASABLE CACHE ADDITIONAL PORTION
1503
1504
DETERMINE WHETHER PROBLEM EXISTS FROM MONITORED INFORMATION ?
NO
YES
1505
IS HARDWARE OTHER THAN STORAGE APPARATUS IN OVERLOADED STATE ?
YES
NO
1506
PORT
IDENTIFY MEMBER IN JOB OVERLOADED STATE ?
LOADS OF PORTS AND HDDS ARE NORMAL
HDD
A
1519
DETERMINE HOW TO INCREASE CACHE ALLOCATION QUANTITY TO CACHE GROUP PERTAINING TO LU FOR STORING DATA IN OVERLOADED HDD
1507
DETERMINE HOW TO INCREASE CACHE ALLOCATION QUANTITY TO CACHE GROUP USED BY JOB RAISING PERFFORMANCE PROBLEM
1508
CREATE REQUEST FOR DATA MIGRATION FROM OVERLOADED HDD
1525
1509
IS CACHE ALLOCATION AMOUNT SUFFICIENT ?
YES
NO
IF POSSIBLE, ISSUE COMMAND OF CHANGING CONFIGURATION TO REDUCE LOAD OF MEMBER IN OVERLOADED STATE
DETERMINE HOW TO CHANGE I/O PERFORMANCE SETTING FOR SQUEEZING I/O PROCESSING AMOUNTS OF OTHER JOBS SHARING OVERLOADED HDD
1517
B
ISSUE COMMAND TO CHANGE CACHE ALLOCATION QUANTITY AND COMMAND TO CHANGE I/O PERFORMANCE SETTING
1521
C
PROCESS END
1530

FIG. 21

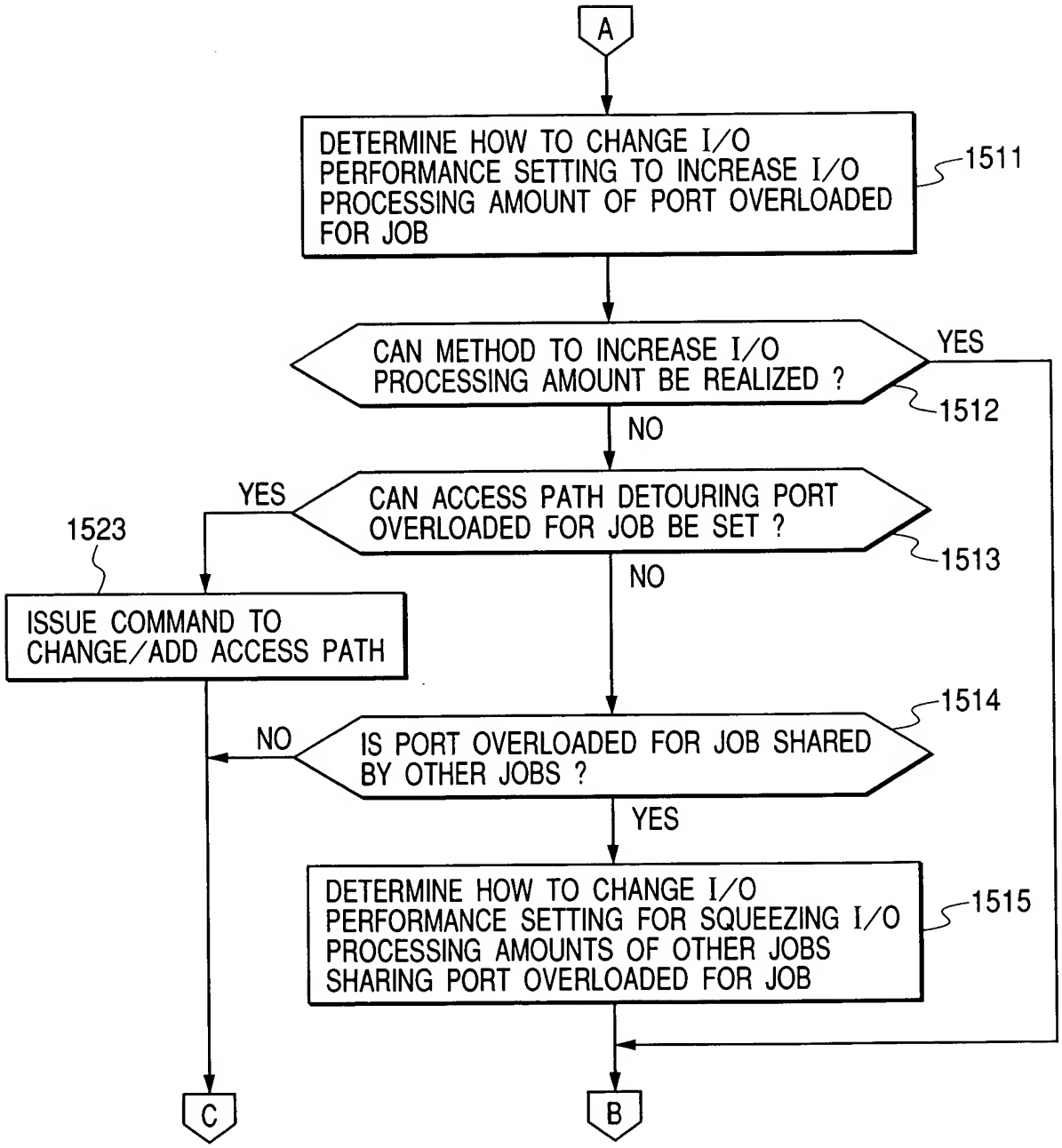

A
DETERMINE HOW TO CHANGE I/O PERFORMANCE SETTING TO INCREASE I/O PROCESSING AMOUNT OF PORT OVERLOADED FOR JOB
1511
CAN METHOD TO INCREASE I/O PROCESSING AMOUNT BE REALIZED ?
YES
1512
NO
CAN ACCESS PATH DETOURING PORT OVERLOADED FOR JOB BE SET ?
YES
1523
1513
NO
ISSUE COMMAND TO CHANGE/ADD ACCESS PATH
1514
NO
IS PORT OVERLOADED FOR JOB SHARED BY OTHER JOBS ?
YES
DETERMINE HOW TO CHANGE I/O PERFORMANCE SETTING FOR SQUEEZING I/O PROCESSING AMOUNTS OF OTHER JOBS SHARING PORT OVERLOADED FOR JOB
1515
C
B

FIG. 22

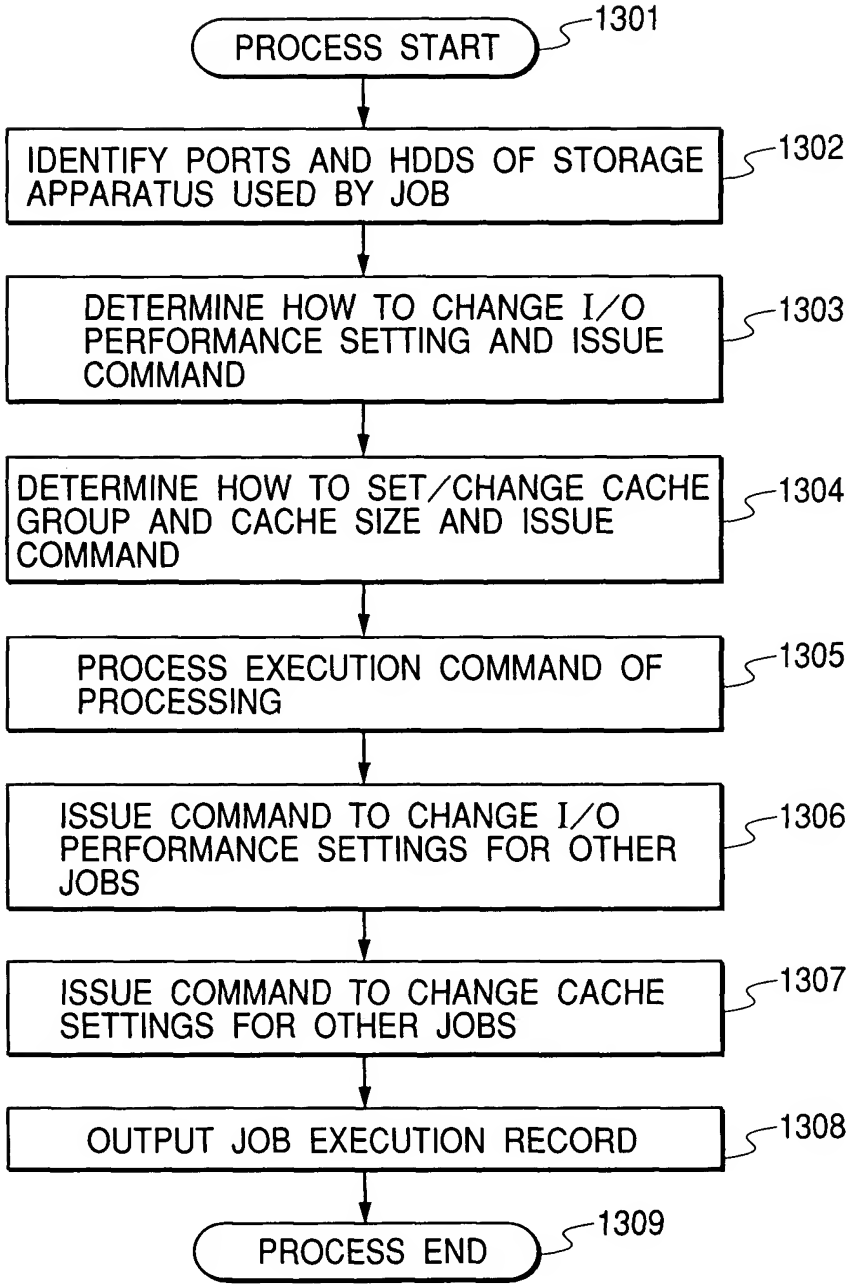

PROCESS START
1301
IDENTIFY PORTS AND HDDS OF STORAGE APPARATUS USED BY JOB
1302
DETERMINE HOW TO CHANGE I/O PERFORMANCE SETTING AND ISSUE COMMAND
1303
DETERMINE HOW TO SET/CHANGE CACHE GROUP AND CACHE SIZE AND ISSUE COMMAND
1304
PROCESS EXECUTION COMMAND OF PROCESSING
1305
ISSUE COMMAND TO CHANGE I/O PERFORMANCE SETTINGS FOR OTHER JOBS
1306
ISSUE COMMAND TO CHANGE CACHE SETTINGS FOR OTHER JOBS
1307
OUTPUT JOB EXECUTION RECORD
1308
PROCESS END
1309

FIG. 23

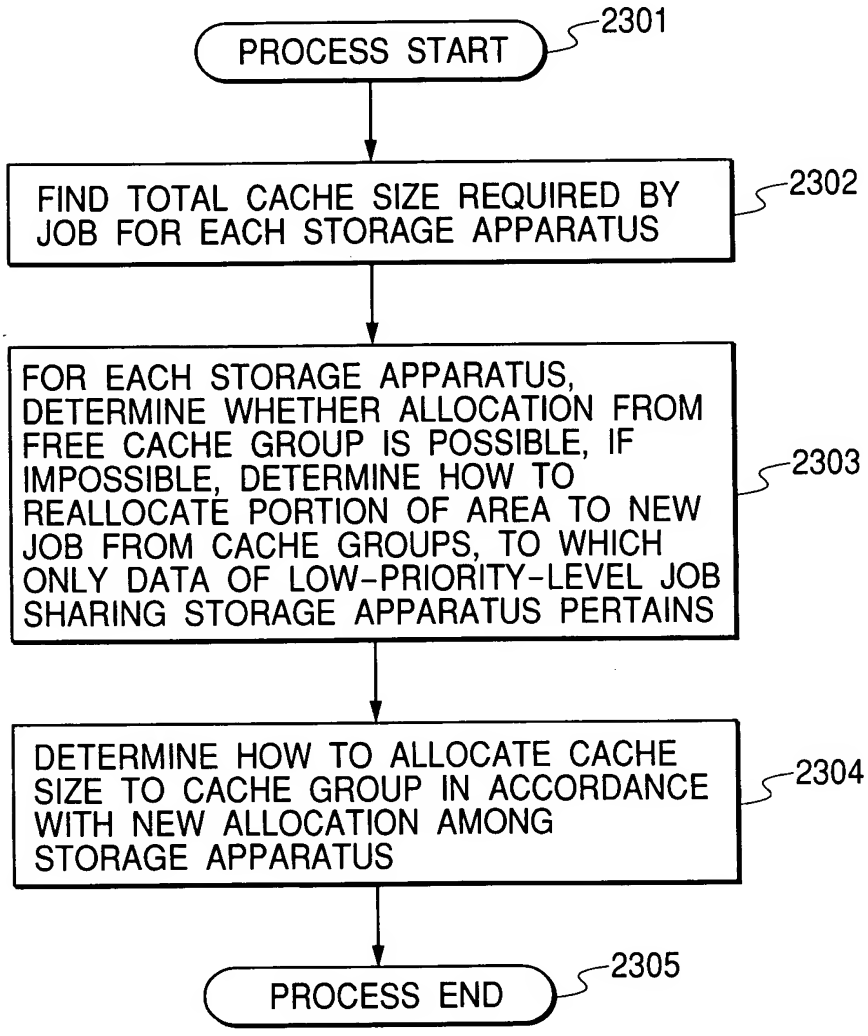

PROCESS START
2301
FIND TOTAL CACHE SIZE REQUIRED BY JOB FOR EACH STORAGE APPARATUS
2302
FOR EACH STORAGE APPARATUS, DETERMINE WHETHER ALLOCATION FROM FREE CACHE GROUP IS POSSIBLE, IF IMPOSSIBLE, DETERMINE HOW TO REALLOCATE PORTION OF AREA TO NEW JOB FROM CACHE GROUPS, TO WHICH ONLY DATA OF LOW-PRIORITY-LEVEL JOB SHARING STORAGE APPARATUS PERTAINS
2303
DETERMINE HOW TO ALLOCATE CACHE SIZE TO CACHE GROUP IN ACCORDANCE WITH NEW ALLOCATION AMONG STORAGE APPARATUS
2304
PROCESS END
2305

FIG. 24

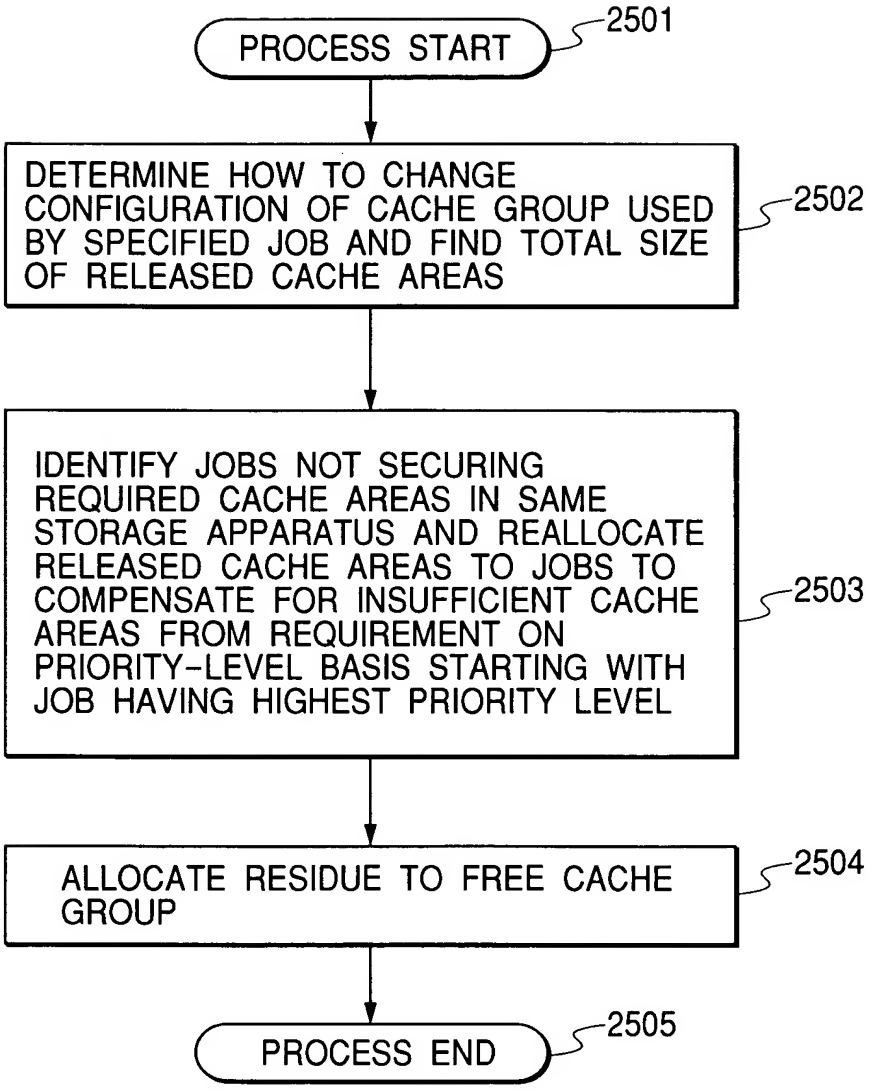

PROCESS START
2501
DETERMINE HOW TO CHANGE CONFIGURATION OF CACHE GROUP USED BY SPECIFIED JOB AND FIND TOTAL SIZE OF RELEASED CACHE AREAS
2502
IDENTIFY JOBS NOT SECURING REQUIRED CACHE AREAS IN SAME STORAGE APPARATUS AND REALLOCATE RELEASED CACHE AREAS TO JOBS TO COMPENSATE FOR INSUFFICIENT CACHE AREAS FROM REQUIREMENT ON PRIORITY-LEVEL BASIS STARTING WITH JOB HAVING HIGHEST PRIORITY LEVEL
2503
ALLOCATE RESIDUE TO FREE CACHE GROUP
2504
PROCESS END
2505

FIG. 25

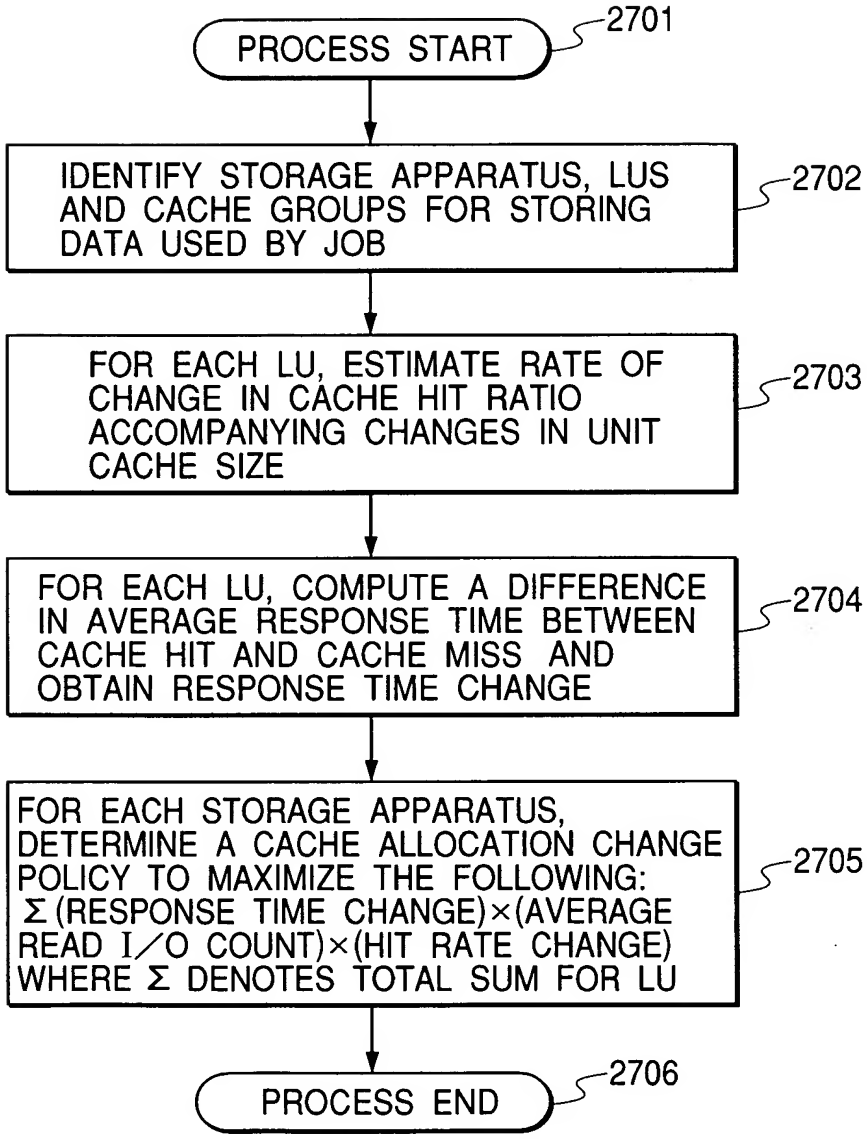

PROCESS START
2701
IDENTIFY STORAGE APPARATUS, LUS AND CACHE GROUPS FOR STORING DATA USED BY JOB
2702
FOR EACH LU, ESTIMATE RATE OF CHANGE IN CACHE HIT RATIO ACCOMPANYING CHANGES IN UNIT CACHE SIZE
2703
FOR EACH LU, COMPUTE A DIFFERENCE IN AVERAGE RESPONSE TIME BETWEEN CACHE HIT AND CACHE MISS AND OBTAIN RESPONSE TIME CHANGE
2704
FOR EACH STORAGE APPARATUS, DETERMINE A CACHE ALLOCATION CHANGE POLICY TO MAXIMIZE THE FOLLOWING: Σ(RESPONSE TIME CHANGE)×(AVERAGE READ I/O COUNT)×(HIT RATE CHANGE) WHERE Σ DENOTES TOTAL SUM FOR LU
2705
PROCESS END
2706

FIG. 26

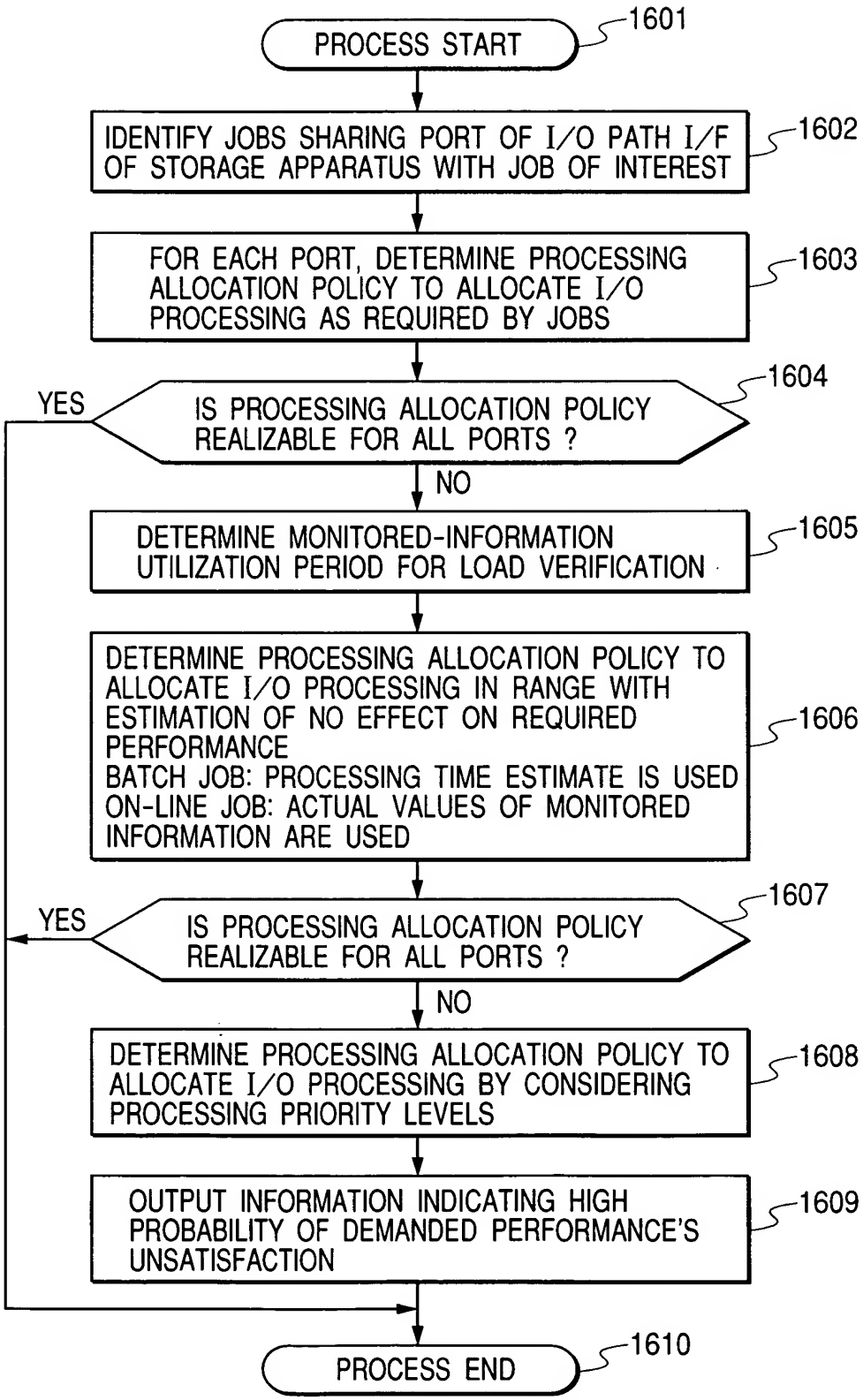

PROCESS START
1601
IDENTIFY JOBS SHARING PORT OF I/O PATH I/F OF STORAGE APPARATUS WITH JOB OF INTEREST
1602
FOR EACH PORT, DETERMINE PROCESSING ALLOCATION POLICY TO ALLOCATE I/O PROCESSING AS REQUIRED BY JOBS
1603
IS PROCESSING ALLOCATION POLICY REALIZABLE FOR ALL PORTS ?
1604
YES
NO
DETERMINE MONITORED-INFORMATION UTILIZATION PERIOD FOR LOAD VERIFICATION
1605
DETERMINE PROCESSING ALLOCATION POLICY TO ALLOCATE I/O PROCESSING IN RANGE WITH ESTIMATION OF NO EFFECT ON REQUIRED PERFORMANCE
BATCH JOB: PROCESSING TIME ESTIMATE IS USED
ON-LINE JOB: ACTUAL VALUES OF MONITORED INFORMATION ARE USED
1606
IS PROCESSING ALLOCATION POLICY REALIZABLE FOR ALL PORTS ?
1607
YES
NO
DETERMINE PROCESSING ALLOCATION POLICY TO ALLOCATE I/O PROCESSING BY CONSIDERING PROCESSING PRIORITY LEVELS
1608
OUTPUT INFORMATION INDICATING HIGH PROBABILITY OF DEMANDED PERFORMANCE'S UNSATISFACTION
1609
PROCESS END
1610

FIG. 27

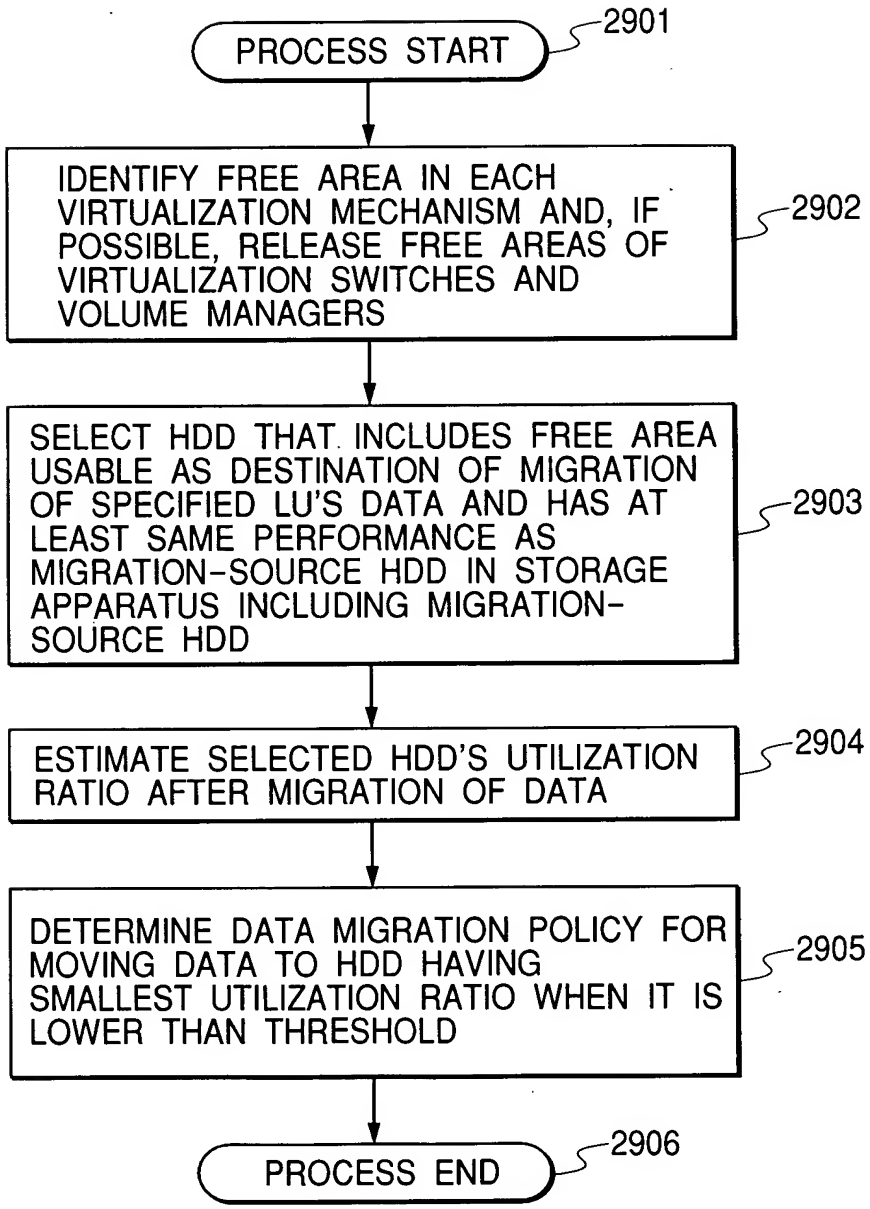
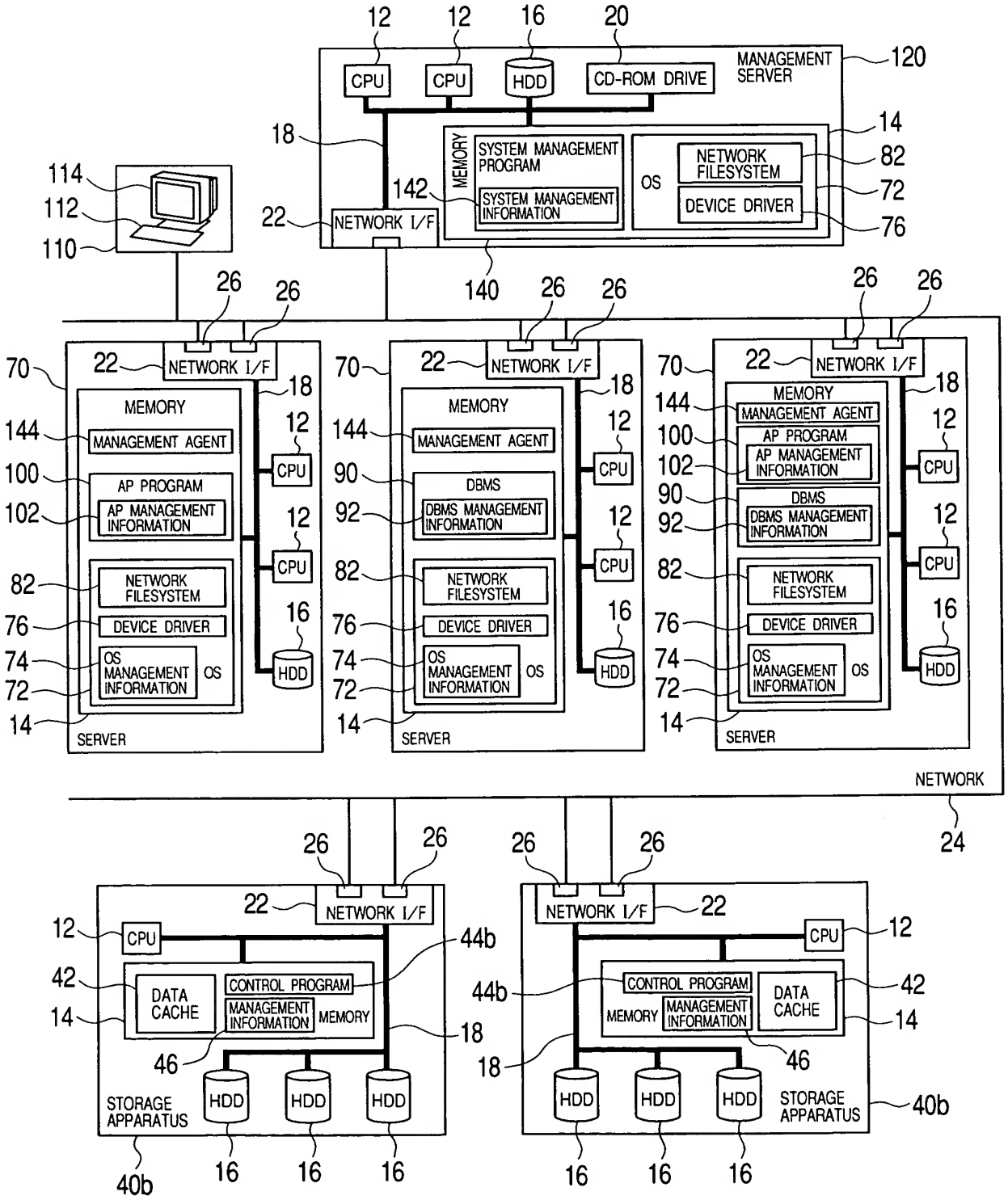

PROCESS START
2901
IDENTIFY FREE AREA IN EACH VIRTUALIZATION MECHANISM AND, IF POSSIBLE, RELEASE FREE AREAS OF VIRTUALIZATION SWITCHES AND VOLUME MANAGERS
2902
SELECT HDD THAT INCLUDES FREE AREA USABLE AS DESTINATION OF MIGRATION OF SPECIFIED LU'S DATA AND HAS AT LEAST SAME PERFORMANCE AS MIGRATION-SOURCE HDD IN STORAGE APPARATUS INCLUDING MIGRATION-SOURCE HDD
2903
ESTIMATE SELECTED HDD'S UTILIZATION RATIO AFTER MIGRATION OF DATA
2904
DETERMINE DATA MIGRATION POLICY FOR MOVING DATA TO HDD HAVING SMALLEST UTILIZATION RATIO WHEN IT IS LOWER THAN THRESHOLD
2905
PROCESS END
2906

FIG. 28


MANAGEMENT SERVER
120
CPU
CPU
HDD
CD-ROM DRIVE
MEMORY
SYSTEM MANAGEMENT PROGRAM
SYSTEM MANAGEMENT INFORMATION
OS
NETWORK FILESYSTEM
DEVICE DRIVER
NETWORK I/F
NETWORK
SERVER
MANAGEMENT AGENT
AP PROGRAM
AP MANAGEMENT INFORMATION
DBMS
DBMS MANAGEMENT INFORMATION
OS MANAGEMENT INFORMATION
STORAGE APPARATUS
DATA CACHE
CONTROL PROGRAM
MANAGEMENT INFORMATION
HDD